DISCOVERY

Explosions in the sun's atmosphere (see article "Films and Scientific Research")

APRIL

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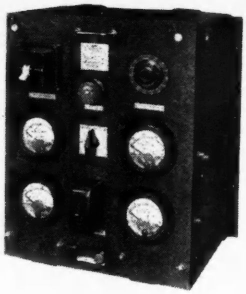

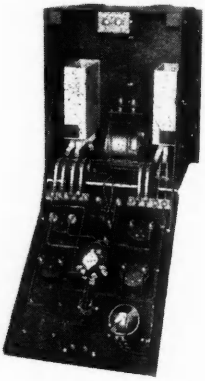

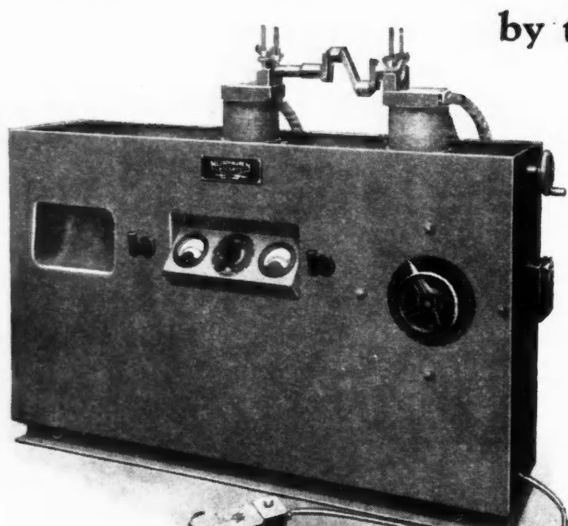

DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

April, 1950 Vol. XI. No. 4

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Advertisement Office: Temple Chambers, Temple Avenue, London, E.C.4. Tel. City 6537 (Three Lines)
All Subscriptions, Distribution and Business Communications to Jarrold & Sons Ltd., Norwich. Tel. Norwich 25261

The Progress of Science

Fertilisers and Food

SIR JOHN RUSSELL told the British Association last summer that "the most hopeful way of increasing world food supplies is by more intensive cultivation of the land already in use," and he stressed the great increase which could be brought about by the use of more fertilisers throughout the world. The world is still a very long way from making the fullest use of fertilisers.

The first so-called 'artificial' fertiliser—superphosphate, from which Lawes made enough money to start the Rothamsted Experimental Station—was produced in England over a century ago. The range of fertilisers available has been expanding steadily ever since. No country, except perhaps Holland, has pioneered the use of fertilisers more than Britain, but it is of significance that the greatest expansion in their use here occurred during the second World War, an expansion which has gone on in the post-war years because of Britain's continued food problems. Yet in many parts of the world, where food supply problems have been for generations more severe than those of Britain since 1940, fertilisers have scarcely been used. Soils have produced that amount of food which their nature permits and the possibility of improving their inherent fertility has not been considered. The new F.A.O. book entitled *Efficient Use of Fertilisers* (available from H.M. Stationery Office) is virtually a monograph on fertiliser use intended to assist agricultural administrators and advisers all over the world, and is one of the most practical publications yet sponsored by the United Nations. It has been prepared by thirty-six eminent soil scientists from fourteen countries, who have presented their material clearly and simply. The experience of fertiliser-using countries is digested in this book so that it may be applied by those countries which still have to make a beginning.

An American diagram in the book shows admirably the enormous influence of soil acidity and alkalinity upon the availability of plant nutrients. Crops cannot obtain an adequate supply of the essential elements unless those nutrients can pass into the soil solution, and the ability of nutrients to do so—their 'availability'—depends upon the degree of looseness or tightness with which the soil itself holds them. This is mainly a chemical consideration, and it applies to nutrients added in fertiliser dressings as well as to the nutrients already held in the soil. Only with a narrow range—roughly, between the points of slight acidity and slight alkalinity (*p*H6 and *p*H8)—are all the essential nutrients reasonably available. It is a simple matter today to find out what the *p*H of soil is; it is not always simple, however, to adjust the *p*H of an area of farmland so as to ensure that any fertiliser applied to that land benefits future crops to the maximum extent. Excess alkalinity is harder to adjust than excess acidity, but fortunately it is the trace elements rather than the major elements whose availability is severely reduced by high alkalinity as can be readily seen from the diagram.

Another basic factor for the efficient use of fertilisers is the amount of moisture in the soils. Nitrogenous fertilisers give remarkable food responses in moister areas, but in dry regions—for example, in Australia—they have been less effective, and in that country enrichment in nitrogen is more effectively obtained by including in the rotation; instead of adding mineral nitrogen, phosphatic fertilisers are applied (and sometimes trace nutrients) to promote the growth of the clovers. In many poor-cropping areas, irrigation should precede the introduction of fertilisers. The necessity for complementary additions of organic matter to soils is stressed. Greater attention to the recovery of organic wastes and greater attention to their hygienic handling are both strongly urged.

Recent developments from the more progressive fertiliser-using countries are described. Of these, the most important example is probably that of fertiliser placement—the application of dressings in rows or bands with the seed or close to it as opposed to the older method of broadcast scattering. By reducing the contact of the fertiliser with the soil, the extent to which the nutrient content is 'fixed' (that is, made unavailable) by the soil is reduced. Subject to the risk of damage to seed by certain types of fertiliser thus applied, these new methods have given good results with lessened amounts of fertiliser; and they have been particularly useful for soils whose 'fixing' capacities have been difficult to correct by other means. In parts of the world where soils are generally less fertile than Western Europe or North America, placement may not merely

improve fertiliser efficiency; it might be found to make all the difference between an area being agriculturally useful, or agriculturally futile because the crop field was out of all proportion to the money spent on cultivation.

Can enough fertiliser be provided? Sir John Russell has already pointed out that "the necessary fertilisers are producible in almost unlimited amounts". In the F.A.O. book an excellent survey of the world's resources and fertiliser industry confirm this. Much more to the point is the question whether the world is yet willing to pay for their cost of production. "The extent to which a farmer can use purchased fertiliser . . . depends on his financial resources and on the price relationship of those materials to his produce. Even if he has the necessary technical knowledge, his economic position is likely to have the strongest influence." The fact must be faced that in those parts of the world where fertiliser use needs the greatest expansion the farmers and growers are the poorest. Economic conditions as well as soil conditions must be improved as a prerequisite for the successful introduction of fertilisers. Enlightened national, and even international, economic assistance seems necessary if the world soils are to make a fuller use of the fertiliser idea. In this, as in other F.A.O. tasks, the politico-economic problem is tougher than the technical or educational problem. A larger proportion of the world's fast rising population may have to see the ghost of Malthus walk more closely before this old and well-established scientific idea is permitted to drive the ghost away.

Gilchrist Thomas's Centenary

HAD it not been for the discoveries of Sidney Gilchrist Thomas, born 100 years ago on April 16th, it is unlikely that steel production in Europe could ever have come to exceed 10 million tons. Thomas lived only 35 years, but the impact of his discovery of the 'basic' steel-making process was immediate and enormous, and its fuller implications are still being explored today.

In the 'basic' process Thomas provided a means of removing phosphorus from the charge of a steel-making furnace. This more than doubled the iron ore available for exploitation throughout the world, which had hitherto been confined to the use of phosphorus-free ores, such as those of Cumberland and North Lancashire.

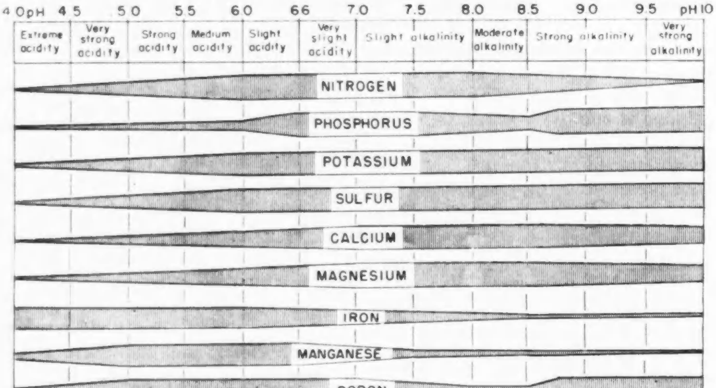
The problem of phosphorus removal had exercised the leading metallurgical brains for twenty years or more—ever since the first attempts (1856–7) to use Henry Bessemer's method of 'steel-making without fuel' had been a fiasco. Bessemer himself, and Siemens, too, had been baffled in their attempts to solve it, and had been driven back on the use of pure haematite ores, leaving untouched the vast deposits of low-grade ores scattered all over the world.

What Thomas grasped was that phosphorus in the iron could only be eliminated if it could first be oxidised to phosphoric acid and then attracted to a strong base in the slag. For this purpose a basic lining would have to be used, and he hit upon magnesian limestone. While a clerk at the Thames Police Court (and, incidentally, the best clerk they ever had, according to all reports) Thomas and his cousin Percy Gilchrist carried out many experiments with improvised equipment at the South Wales works where Gilchrist was employed. Later, they were given better though still inadequate facilities at Blaenavon and Dowlais works.

The first intimation of success was contributed by Thomas in a discussion at the Iron and Steel Institute in May 1878, and *Engineering* reported that "amid some laughter and other signs of incredulity he stated that he could remove by his process as much as 99·9% of phosphorus".

Thomas and Gilchrist received another rebuff when their paper on the subject due for discussion at the autumn meeting of the same year was dropped from the programme. However, Thomas succeeded in interesting Windsor Richards, manager of Bolckow, Vaughan's works (now Dorman, Long and Company) and after many difficulties in the manufacture of the bricks had been overcome, successful trials were carried out on April 4, 1879.

The world was immediately at the inventors' feet. The discovery was seen to be of the utmost importance to France, Germany and Sweden, where hitherto almost useless highly phosphoric ores abounded, and of ultimate importance to the U.S.A., where about half the huge ore deposits of the Great Lakes are phosphoric. In the twenty



Availability of Plant Nutrients and the Soil Reaction

This diagram illustrates the general relation between soil reaction (pH) and the availability of plant-nutrient elements. Each element is represented by a band as labelled. The width of the band at any particular pH indicates the extent to which the element is available for absorption by the plant; the wider the band, the greater the availability of the element.

years following Thomas's discovery Germany's steel output increased ninefold to 6 million tons, over 95% of it being basic.

Today 90% of world output is by the basic method, without which production on the modern scale would be quite impossible. Thomas's own experiments were on Bessemer converters, and steel made in basic-lined converters is still known as Thomas on the Continent. But Thomas saw that basic linings were as applicable to open-hearth furnaces as converters, and in this country, as in the U.S.A., the great bulk of steel manufacture is by this means.

Another valuable product from the process is basic slag, which is a valuable fertiliser because of its high phosphorus content. Thomas, again, perceived its value, and experimented on means of rendering the P_2O_5 content soluble. The Germans, however, first hit on the simple expedient of grinding the slag to an impalpable powder, in which form it is now used.

Thomas himself seems to have had a most lively and attractive character. He was a rare example of a scientist of insight and pertinacity perhaps amounting to genius, who was actuated very largely by a desire for gain. It was a chance remark by a lecturer, to the effect that a fortune awaited the solver of the phosphorus problem in steel-making, that led Thomas to harness his amazing energies and his passion for applied chemistry to this particular goal. He attained his goal, but at the total expense of his health. Throughout his life he had a strong feeling for social justice, and on his death he entrusted his sister to expend his fortune for the benefit of the oppressed. This task she discharged in association with Margaret Bondfield and many others.

It is of interest to note that development of Thomas's discoveries is by no means at an end. Work at Corby and Ebbw Vale on low nitrogen basic converter steels, and by the British Iron and Steel Research Association and several steel firms on improved designs of basic open hearth furnace roofs show evidence of continued progress.

Making Heat Rays Visible

THE detection of infra-red radiation is not a simple problem. One of the methods developed during the war for military applications made use of certain luminiscent materials (or phosphors) with unusual properties of very great theoretical interest. These materials are crystalline powders which convert invisible ultra-violet radiations, cathode rays or X-rays, into visible light. The earliest scientific law concerning the behaviour of these materials, enunciated by Sir G. G. Stokes in 1852, states that the light emitted by a luminescent material is always of a longer wavelength than that of the radiation by which it is excited. That is to say, you can convert ultra-violet of short wavelength into visible light, blue light into green and green into red, but that the reverse transformations cannot take place. The explanation of this law came later with the development of the quantum theory of light which showed that light consisted of small packets of energy, called quanta. The shorter the wavelength of the light, the greater the energy of the quanta. Clearly a quantum absorbed by a crystal cannot come out again with more energy than it started, and in fact it will probably have less; the wavelength of the emitted

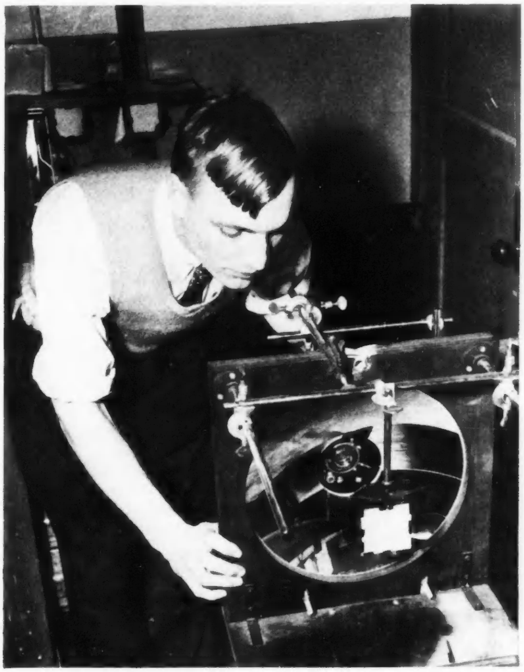


FIG. 1.—Nelson R. Nail, of Kodak Research Laboratories, checks a 'heat radiation' camera. The heat rays from a hot object such as a boiling kettle can be transformed into radiation capable of affecting a photographic plate and so enable a picture of the hot object to be taken in the dark. The small white square in front of the camera is a phosphor screen, on which an infra-red image of the hot object is thrown by the concave mirror. The screen is simultaneously flooded with ultra-violet radiation, and a time exposure taken through the hole in the mirror.

light is therefore longer than that of the exciting radiation. At first sight it would seem impossible to use such a substance to detect the very long wavelengths of infra-red rays. However, many fluorescent substances have the capacity to store up some of the energy they absorb, releasing it as light after an interval which may be anything from a fraction of a second to several years after it was absorbed, depending on the circumstances. This stored energy can be released by infra-red rays.

To understand how this happens we must consider the mechanism of the whole process of luminescence in a solid. When the short wavelength exciting quantum is absorbed an electron is ejected from its normal place in the crystal, leaving behind what is called a 'positive hole'. Both electron and positive hole may then wander through the crystal, but the positive hole is very likely to be captured by a 'luminescence centre'. If the electron meets a luminescence centre which has captured a hole the electron returns to the hole and a quantum of light is emitted. These processes are indicated in the diagram of Fig. 2. in which distance through the crystal is represented by the horizontal axis (X), and the energy of the electrons (E) is measured vertically. On theoretical grounds no electrons can have energies in the gap between the top of the 'filled

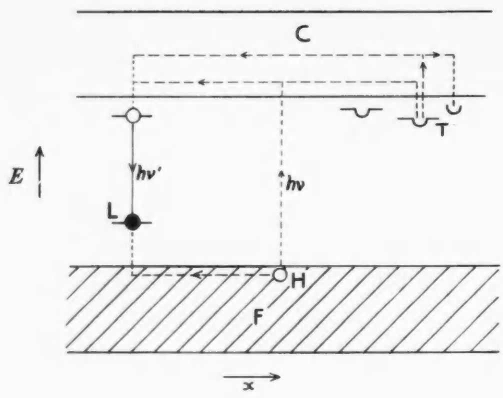


FIG. 2.—Schematic electron energy diagram for crystalline phosphor activated by atoms of an impurity. C. Conduction energy band; F. Filled energy band; H. Positive hole; L. Luminescence centre; T. Electron traps; hv. Absorbed quantum; hv. Emitted quantum.

band' and the bottom of the 'conduction band' except where localised levels occur at the various kinds of centre. The transfer of an electron from one band or level to another across this 'forbidden region' is accompanied by the absorption or emission of one quantum of radiation. If the jump is a large one the quantum has a high energy and the radiation a short wavelength, and vice-versa. The levels marked T, close under the bottom of the conduction band, are electron traps. Normally empty, they may capture electrons from the conduction band and will not release them unless either the temperature of the phosphor is raised, when the electrons are shaken out by the increased thermal vibrations, or the phosphor is irradiated with infra-red. Once released from its trap the electron is more likely to encounter an empty luminescence centre than another trap, and so recombine with the hole with the emission of light.

The problem therefore, from the point of view of infra-red detection, is to find a material containing many electron traps. In most phosphors the pure material is not itself luminescent, but becomes so when the proper impurities are present to provide the luminescence centres. An important outcome of the war-time research was to establish the fact that electron traps could also be introduced by means of impurity atoms, and that different impurities were often necessary for traps and centres.

Two main types of infra-red sensitive phosphor were developed. The most effective was a strontium sulphide containing a few parts in ten thousand of two rare elements, Europium and Samarium. Here the Samarium provides the traps and Europium the luminescence centres. The second type was based on the well known zinc-sulphide phosphor, but contained traces of lead and copper. In this case the exact role of the lead is still uncertain, and research still continues in the hope of discovering the precise nature of the electron traps.

The amount of energy stored by these materials is remarkably high. A cube of one phosphor 1/10th of a millimetre inside, if fully excited by ultra-violet to charge up all the traps, and then stimulated by infra-red, can maintain a brightness one hundred times greater than the visual threshold for over one hour before its sensitivity to the infra-red has been reduced to half its initial value.

Infra-red has other effects on phosphors which so far have not received any very satisfactory explanation. For instance, in some cases, if infra-red falls on a phosphor which is being continuously excited by ultra-violet radiation the intensity of the fluorescence falls to a low value, but rises again as soon as the infra-red is cut off. A probable explanation depends on the fact that in addition to luminescence centres and traps most phosphors also contain 'killer centres' at which electrons and holes may recombine without the emission of visible radiation. An infra-red quantum may excite an electron from the filled band into the hole in the luminescence centre. We now have a hole in the filled band which can wander about and may be captured by a killer centre. This process can also occur if the phosphor is heated, and in fact all phosphors when heated to a high enough temperature loose their fluorescence efficiency. The temperature at which this drop in efficiency occurs can be very much reduced by the incorporation of some killer centres. The full understanding of their effects is bound up with the general problem of the behaviour of electrons in crystals, and is now the subject of intensive research in such diverse fields as luminescence, semi-conductivity, solid rectifiers, electrical breakdown of insulators, photoconductivity, and others.

Heat Photography

Recently various peaceful applications of these war-time results have been developed. An outstanding example is the new method of heat photography announced by the Kodak Research Laboratory of Rochester, U.S.A.

Hot bodies emit infra-red rays over a wide band of wavelengths, and the higher the temperature of the body the greater is the proportion of the shorter wavelengths. Thus 'white heat' is hotter than 'red heat', and at lower temperatures the radiation is of progressively longer wavelengths. For many years it has been possible to take photographs on specially sensitised plates by means of radiation of wavelengths between 7000 and 12,000 Ångström units. This has enabled the temperature distribution over hot bodies such as furnaces or internal combustion engines to be studied, but the method has been limited to bodies hotter than about 500° C. owing to the relatively low sensitivity of the plates for the longer infra-red wavelengths.

The new method announced is extraordinarily sensitive and can detect the differences in the radiation emitted by bodies right down to room temperature. It has even been possible to photograph a block of ice by means of the radiation from its surroundings. Instead of using a sensitised photographic plate the infra-red image is projected by a spherical mirror on to a screen made of a special phosphor of the kind whose fluorescence is quenched by infra-red. The screen is simultaneously flooded by ultra-violet light, and is photographed by means of a normal camera (see Fig. 1.). Where the infra-red image is brightest the fluorescence of this screen is quenched, and where the infra-red is weak the screen is bright. Some examples of pictures taken by this technique are shown in Fig. 3.

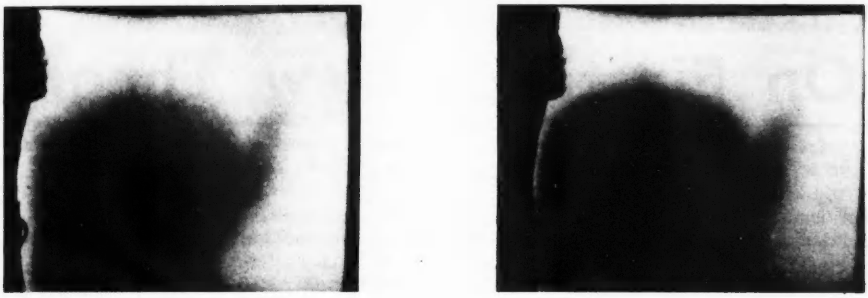


FIG. 3.—Photographs taken by the technique of Fig. 1 of a kettle on an electric hot-plate. (*Left*) The hot-plate is very hot, while the water in the kettle is at 70° C. (*Right*) In this picture the water is boiling, and the hot-plate has cooled to nearly the same temperature.

An alternative method which can be used to determine the actual temperature over the whole surface of the hot body under investigation is to paint the object with a phosphor whose colour and efficiency changes in a known way over the temperature range concerned. When examined under ultra-violet radiation the temperature distribution will be revealed by the brightness and colour of the fluorescence. An idea of the sensitivity of this technique is given by the following simple experiment. A man's hands are painted with a suitable phosphor and he holds one above his head for a few minutes. On placing both under an ultra-violet lamp the hand which was raised fluoresces more brightly than the one which was not, showing clearly the small temperature drop which occurs in the raised hand owing to the reduction in its blood supply. Such a comprehensive picture of the temperature distribution of an object, which can be recorded in still or motion pictures, has not hitherto been available to engineers and scientists. It is expected to find a large number of applications.

(Fig 1 *comes from G. F. J. Garlick's paper in Reports on Progress in Physics, Vol.* 12, 1948-49, *published by the Physical Society.*)

Fluorine and Dental Caries

IN areas where fluorine occurs naturally in the water supply, even at one part per million, the prevalence of dental decay is 50% to 65% below normal The U.S. National Institute of Dental Research followed up this discovery and tried adding fluorine to the public water supply for the Grand Rapids district of Michigan. The experiment has gone on for five years, and will continue for at least another five A definite trend towards reducing decay has already been shown. Dr. H. T. Dean, Director of the Institute, has stated that if this trend persists for another year fluorine addition to water can be safely regarded as a practical and economical means of considerably reducing dental caries in large population groups.

In Britain a test is to be made to see whether children's teeth can be protected against decay by application of a fluoride solution. There are only a few areas in Britain where the water contains fluorine, but there are grounds for believing that comparable protection may be obtained by wetting the teeth periodically with a solution containing fluoride. It is this treatment that will be fully tested under a Ministry of Education scheme over a period of some years, the children's teeth being examined annually. Because of the shortage of dentists this treatment can only be made available to a limited number of children in different parts of the country. It will be given by the staffs of a number of dental hospitals and of Local Education Authorities. The methods of selecting the children may vary according to local arrangements, but no child will receive the treatment without the parent's consent. Both boys and girls will be included, but it is not proposed at present to give the treatment to any child over 12 years.

Everyone obtains a certain amount of fluorine from food. According to recent reports tea and beer are relatively rich sources of this element. It has been estimated that the total food-bone fluorine in the diets of children from 1 to 12 years old is about 0·25 to 0·3 milligram daily, not including that contained in drinking water. It has been suggested that for purposes of dental health the fluorine intake should be supplemented to the tune of 1 milligram per day.

Hydrogen as a Nuclear Fuel?

IN his lecture to the Royal Society of Arts in March Prof. M. L. Oliphant drew attention to the possibilities—the remote possibilities—of hydrogen as a nuclear fuel. He reminded his audience that 1 lb. of hydrogen transformed into helium would produce about 100 million kilowatt-hours of heat energy, or about 130 million horsepower for an hour. Thus hydrogen as nuclear fuel would be about ten times as good, weight for weight, as uranium. There are possible ways in which an explosive reaction of this type can be produced by utilising the very high temperature and pressures developed in the explosion of an atomic bomb, but so far there is no clue to a method for bringing about the reaction in a controllable way. Prof. Oliphant then proceeded to speculate on the possibility that nuclear scientists may one day discover how to do this.

If we accept as the desirable power level for civilisation that every individual should utilise, on the average, 1 kilowatt of power continuously, we can calculate that 3000 million inhabitants of the earth could be supplied with power from the hydrogen of the sea for 1000 million million years. If this remote possibility was realised, he said, mankind would have no need to look elsewhere than to the sea for all the power it can conceivably use in the lifetime of the solar system.

IN this article Prof. Infeld, who was one of Einstein's collaborators and co-author with Einstein of the popular work, "Evolution of Physics", describes the aim of Einstein's new theory and considers the background to the theory.

On Einstein's New Theory

Professor LEOPOLD INFELD

IN 1905, when our century was still young, Einstein was twenty-six and a clerk in the Swiss Patent Office. In that year, he wrote a paper that changed the face of science. It contained the basic ideas of Special Relativity Theory, and revolutionised the concepts of space and time. Einstein was the first man on our planet to deduce the relation between mass and energy—a simple but fundamental relation that, forty years later, played a very significant part in the discovery and utilisation of atomic energy. Thus, forty-five years ago, the first Einstein revolution in science was accomplished.

If Einstein had done nothing since then, his name would live for centuries in the history of science. Yet only ten years later, around 1915, Einstein finished his work on the General Relativity Theory. Here, for the first time since Newton, a new theory of gravitation was formulated. This theory explains how the earth attracts the moon, how the planets move around the sun, how double-stars revolve around each other, and what is the structure of our universe. As a logical system, Einstein's theory of gravitation is superior to Newton's old theory. Whenever the conclusions of Newton's and Einstein's theories differ, observation—the supreme judge of all physical theories—seems to favour Einstein's. Thus, thirty-five years ago, the second Einstein revolution in science was accomplished.

The characteristic feature of Einstein's genius is his complete independence of mind. He accepts no man's dogma; he thinks for himself, always and about everything. Since 1918, up to the year that has just passed, this is, for over thirty years, he has worked on one of the deepest and most difficult problems in science: to find a theory that would embrace the large-scale phenomena (as his old theory of gravitation did) and, at the same time, the small-scale phenomena concerning the elementary particles of which atoms are built. Many scientists believed (and still believe) that such an ambitious plan can never be realised, that the laws that govern the stars and the nebulae are different from those that govern the electrons in the atom, that no unifying principle embracing both is, or ever will be, possible. Yet on this very problem, Einstein has thought incessantly, finding solutions and rejecting them because they did not satisfy his high standards of logical simplicity and beauty. While we were discussing a theory, Einstein often remarked to me: "Could God have created the world this way?" A good physical theory, Einstein feels, must reflect the beauty and the glory of the universe.

Last year, when Einstein was seventy years old, he found what he believes is the solution he has sought for thirty years. The results of his last two decisive steps appeared in *The Canadian Journal of Mathematics*, and in a new edition of *The Meaning of Relativity* (published by the Princeton University Press in America and Methuen in Britain).

Has Einstein solved the great problem of finding one law to embrace both the large- and small-scale phenomena? It may take a long time until mathematical analysis and observation pronounce their verdict—until we find the treasures hidden by Einstein's new equations. Thus no one yet knows whether the third Einstein revolution in science has been accomplished.

The Electromagnetic Field

To understand, even in general terms, the problem on which Einstein has worked for thirty years, we must go back to the nineteenth century, to the time of James Clerk Maxwell, who was the first to create a successful field theory.

From the broadcasting antenna to my radio receiver, the radio waves, that is, the electromagnetic waves, spread with the velocity of light. From the atoms in a neon tube to my eye, light rays (again electromagnetic waves) spread with the velocity of light. Both radio waves and light waves are governed by the same laws, expressed by Maxwell's equations. They tell us how the electromagnetic field changes in space and time, how the electromagnetic waves spread, and what are their physical properties. Maxwell's theory is a field theory because it considers changes in time and in our three-dimensional space. It is very different from a mechanical theory that deals with such problems as the motion of the moon around the earth. In a mechanical theory, the particles and their motion are important; in a field theory, the changes of a field in space and time are.

Yet, in describing the electromagnetic phenomena in the nineteenth and early twentieth centuries, we did not use the field concepts alone. Electrons, that is, negatively charged particles, produce an electromagnetic field while in motion. Thus, in Maxwell's theory, and later in Lorentz's theory, we still find a mixture of the field and particle aspects. Particles (electrons) move in an electromagnetic field and influence the field by their motion. Yet it was the field aspect that was the new and predominant feature of Maxwell's theory.

The electromagnetic field, as its name implies, is a combination of two distinct fields—the electric field and the magnetic field. Consider, for example, the former. The field at a given point and a given time may be characterised by defining (*a*) its strength and (*b*) its direction. For mathematical purposes its strength may be represented by a length, so that the field at any point is represented by a length in a given direction. Imagine the length as a rod placed with one end in the corner of a room and sticking out at an angle to the two walls and a floor. Clearly its length and direction can be specified by stating that to get from the corner to the farther end of the rod one must move first so many inches parallel to the line of intersection

of the floor and one wall, then so many inches parallel to the intersection of the floor and the other wall, and finally so many inches parallel to the intersection of the two walls. Thus we specify the given length and direction in terms of *three* lengths in three mutually perpendicular directions. Similarly the strength of the electric field at a given point and time can be specified by three numbers representing the components of its strength which lie in three given mutually perpendicular directions.

But the field varies with time and place, and so the three numbers will do likewise. Thus to specify the electric field completely we require three mathematical functions, each of which tells how its strength in one of the fixed directions varies with position and time. To specify the magnetic field we need three more such functions. And so the complete electromagnetic field is specified by *six* functions in all.

These functions tell us how the electromagnetic field varies in space and time. But the functions are not independent. Maxwell's equations tell us the relations between them, or in other words, the law which must be obeyed by changes of the electromagnetic field in space and time.

The Gravitational Field

We can now characterise in general terms at least one aspect of Einstein's second revolution: it did for gravitational phenomena what Maxwell's theory did for electromagnetic phenomena.

Newton's theory of gravitation follows the mechanical pattern. Particles (*e.g.* the moon or earth) are attracted by other particles (*e.g.* the earth or sun). In it the concept of field is not developed, nor is the concept of a gravitational field spreading through space in time.

Einstein's theory of gravitation is not an improved version of Newton's theory; it is an entirely new theory based upon new assumptions, logically more satisfactory than those of Newton. Yet the results, which can be tested by observation, are very similar in the two theories. There is a great area of agreement and a small area of disagreement. The most famous new phenomenon, predicted by Einstein's theory only, is that of light rays bending as they pass near the edge of the sun. Indeed, it was this phenomenon, discovered during a solar eclipse when one can see stars near the darkened sun, that started the great fame of relativity theory and its creator. Another difference between the two theories concerns the motion of planets around the sun. The discrepancy between results deduced by the two theories is small, yet detectable in the case of Mercury, the planet nearest the sun. Whenever such disagreement exists and whenever experiment can pronounce its verdict, it seems (to put it cautiously) to favour Einstein's theory of gravitation. But the importance of Einstein's achievement lies rather in the beauty and simplicity of his theory than in the discovery of new phenomena.

The gravitational field in Einstein's theory is characterised by ten functions changing in space and time. They play a role similar to that of the six functions in Maxwell's theory. Einstein's gravitational equations tell us how these functions change in space and time.

We remember that in the electromagnetic theory, we have a mixture of field and particle concepts. The field is produced by the electrons and their motion. Similarly, in Einstein's original theory, the gravitational field is produced by the bodies (stars and nebulae) and their motion. Thus, comparing Maxwell's and Einstein's theories, we have the following analogy:

electromagnetic field	←→	gravitational field
charged particles	←→	gravitational masses
motion of charged particles	←→	motion of gravitational masses.

Our analogy is not complete and in some respects even misleading. We must now mention one novel feature of Einstein's field equations. The gravitational field is influenced not only by the moving gravitational masses but also by the electromagnetic field itself. Thus, the sources of a gravitational field lie in moving masses, in moving charges and in the electromagnetic field. A pure gravitational field can exist without an electromagnetic field. But a pure electromagnetic field cannot exist without a gravitational field.

Physics and Geometry

Let us now adopt the view of 1920, when the structure of Relativity Theory was finished, and without which we cannot understand what happened later. We see one essential difference between gravitational and the electromagnetic field: the gravitational field is a geometrical field; the electromagnetic field is a physical field.

The understanding of the gravitational field as a geometrical field is the result of one of the greatest and most revolutionary ideas that ever entered physics. It is impossible to grasp the importance of Einstein's achievement without being aware of this point. We know the properties of a Euclidian space from our school days: from a point outside a line we can draw one and only one line parallel to the given one. But since the nineteenth century we know that Euclidian geometry is only one of the many possible ones. The simplest case of a non-Euclidian geometry would be, for example, the one experienced by two-dimensional creatures living on the surface of a sphere. They would find that a journey 'straight ahead' (that is, along a great circle) leads them to their point of departure; that the ratio of a circumference to its diameter is smaller than π.

The background of our physical events is a four-dimensional world. There is nothing mysterious about it. Every event, like the death of Julius Caesar, is characterised by the 'place' and time in which it took place. The 'place' of an event is characterised by three numbers, thus together with time we have four. The totality of all possible events forms one four-dimensional world. All this has been known and successfully applied since 1908 when the great mathematician H. Minkowski gave the beautiful four-dimensional mathematical form to Einstein's Special Relativity Theory.

Yet General Relativity Theory goes one important step further. We ask: is our four-dimensional world flat, like the plane in two dimensions? Or is it curved, like a curved surface of two dimensions? The difficulty with these questions is, that whereas we can easily visualise a two-dimensional flat or curved space it is difficult to do so if

the space is four-dimensional. But where our intuition stops, mathematics does not. Even before Einstein's time, the mathematics describing many-dimensional curved spaces was known, though it developed fully only under the impetus of Relativity. The development of this branch of mathematics is connected with the names of Gauss, Lobachevski, Bolyai, Riemann, Ricci, Levi-Civita and others. Let us say here only that a four-dimensional space is characterised by ten functions; that once we know these functions, we know the geometry of such a space; we know whether such a space is curved and how its geometry changes from point to point.

In my room I can characterise the position of the end of my pencil by quoting its distances from the ceiling and two perpendicular walls. Or, generally, a position of a point is designated by three numbers in a given co-ordinate system. In a town, the names of streets and house-numbers form two co-ordinates denoting with sufficient accuracy the positions of its inhabitants on a piece of a surface (at least when they stay at home). Similarly in our four-dimensional world of events we must have a co-ordinate system so as to name the four co-ordinate numbers that denote an event. But besides these we need ten functions that tell us whether the world we describe (in a given but arbitrary co-ordinate system) is flat or not flat, or, as we often say, Euclidian or Riemannian.

We can now formulate Einstein's great and new idea: the ten functions that characterise the geometry of our four-dimensional world are the same ten functions that characterise the gravitational field. A world without masses, without electrons, without an electromagnetic field, is an empty world. Such an empty world is flat. But if masses appear, if charged particles appear, if an electromagnetic field appears, then a gravitational field appears too. If the gravitational field appears then our world becomes curved. Its geometry is Riemannian, that is, non-Euclidian.

Thus the same ten functions characterise the metric and the gravitational field. The word 'metric' indicates the connexion between these ten functions and the geometry of our world. The word 'gravitational' indicates that the same ten functions describe the gravitational phenomena in our world. The fact that we can use either or both these words indicates that the physical gravitational field has its geometric counterpart. Physics—as far as the gravitational field is concerned—is reflected as geometry. The geometry of our world and the gravitational field are shaped, formed by moving masses, charges, and by the electromagnetic field. Thus the connexion:

Physics ←→ Geometry

exists only for the gravitational field. We repeat: the gravitational field is a geometric field too; the electromagnetic field is a purely physical field.

About 1920, General Relativity Theory presented a curious mixture of geometry and physics. To understand Einstein's later endeavours, we must understand his reason for dissatisfaction with the structure of field theories as they were then known. Thus, in Maxwell's equations we have:

given; charges and their motion
unknown: the electromagnetic field.

In Einstein's Relativity Theory, we have:

given: masses, their motion
unknown: the gravitational or metrical field.

In Relativity Theory, the given and unknown form a strange mixture. Mass and energy have no geometrical counterpart. But the field has!

General Relativity Theory was born because of Einstein's dissatisfaction with the classical theory of gravitation. The new theory was born because of his dissatisfaction with General Relativity Theory. Its weak point was the artificial mixture of geometric and physical concepts. But this was not the only weak point. Another one is perhaps still more important.

Both the electromagnetic and the gravitational theories are dualistic theories. In both of these theories, we have sources of the field (charges, particles) and the field itself. Thus we see in both theories a mixture of two concepts: matter and field. It would be philosophically much more satisfactory if we were able to build a unitary theory based on only one of these concepts. The triumphs of field theory were too great to allow us to abandon the field concept. Thus Einstein's aim was to build a pure field theory. In such a theory we would have only field concepts and equations of the field. But we could argue: how can we be satisfied with field equations alone? We know that matter is as real as the stone on which we stumble. The supporter of the unitary field view would say that the existence of what is known as matter should be deduced from the field equations alone. What is regarded as matter is situated in regions in which the field is especially strong. Motion of matter means that the regions in which the field is especially strong change with time. Thus a resting electron has to be represented in a unitary electromagnetic theory by a small region, inside which the field is very strong, and outside of which it dies out quickly. Such a region with a strong, but finite field, represents concentrated energy, that is, matter.

Thus a good field theory describes and interprets matter in terms of strong fields. Thus from the point of view of logical simplicity, great progress would be achieved if both Maxwell's theory and General Relativity Theory were to change into a pure field theory; such a theory would deal only with the concepts of the electromagnetic field (characterised by six functions) and of the gravitational field (characterised by ten functions). But the laws of these fields would have to be changed. Unlike Maxwell's theory and General Relativity Theory, such new theories would have to admit solutions representing matter. The old theories failed to do that!

But even if we were to succeed in formulating a pure field theory, such a theory would still be tainted with another sin. We saw, in the old theories, that the gravitational field was a geometrical field too, but the electromagnetic field was a purely physical field. This division is again artificial, and, according to Einstein, a satisfactory theory ought to have the following features:

1. It ought to be a pure field theory.
2. In it, electromagnetic and gravitational fields ought to be treated on the same footing, that is both should characterise the geometry of our universe.

Thus Einstein tried to remove the sin of a double dualism from our theories: the dualism of field-matter

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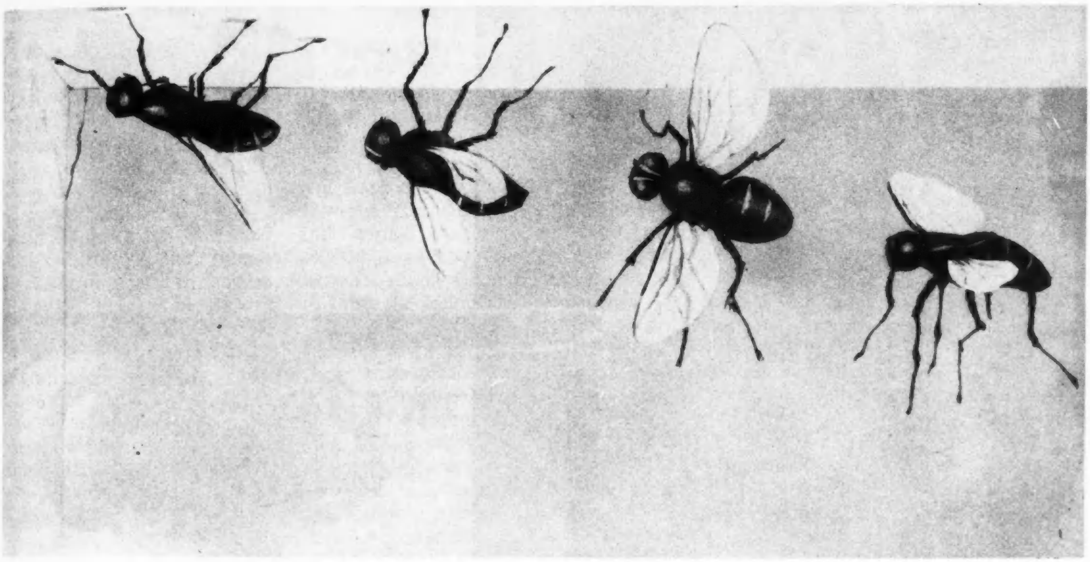


How does a fly land on a ceiling? This question which stumped the scientists on the B.B.C.'s Brains Trust is an example of the kind of question the high-speed cine camera can answer. The artist's impression shows the sequence of actions involved when a fly lands upside down on a ceiling, and was based on analysis of a high-speed film. *(Courtesy, Kodak Ltd.)*

Films and Scientific Research

ANTHONY R. MICHAELIS, Ph.D., B.Sc.

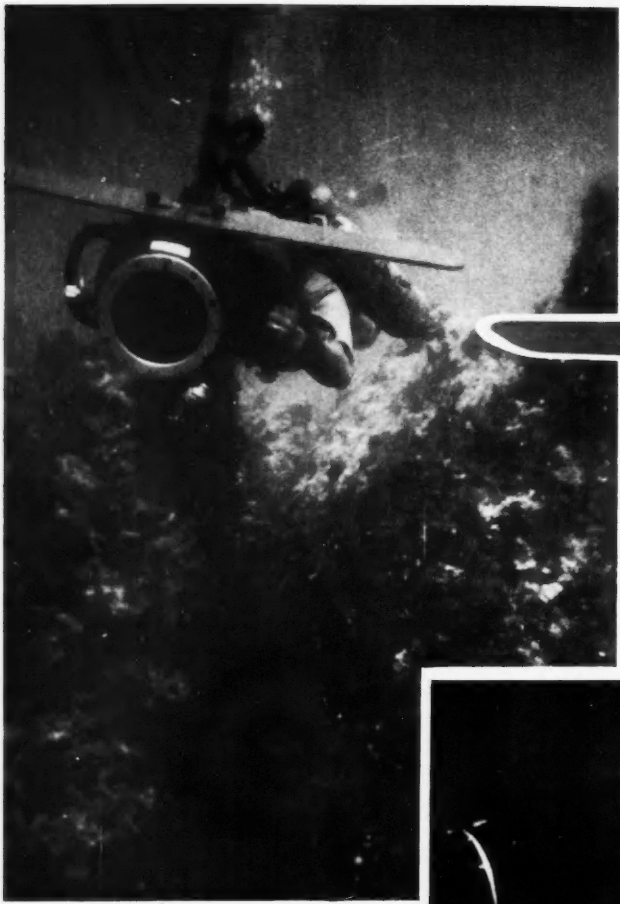
It is not so very long since the first scientific research film was made by the director of the Montmartre Astronomical Observatory, Jansen, who recorded in Japan the eclipse of the sun by the planet Venus. He used a circular Daguerrotype photographic plate which he rotated in the focal plane of his telescope. That was only seventy-five years ago, and since then many research workers have called in the cine camera for help. More and more scientists are using this instrument because it is convenient for recording. Moreover the cine camera can reveal many phenomena that cannot be seen by the unaided human eye.

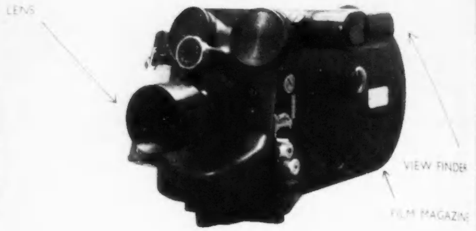
The cine camera has the great advantage that it offers access to a different scale of time. Nowadays it is fairly simple to take a cine film by exposing each frame separately at given time intervals so that on projection at the standard speed of 16 to 24 frames per second, the movement will appear to be speeded up. This technique, which can speed up movement by as much as 10,000 times, is called time-lapse cinematography. The opposite effect can be achieved by the use of special high-speed cameras: by taking pictures at the rate of 160–8000 frames per second, and then projecting them at standard speed an event will appear to be slowed down 10–500 times. These are very obvious advantages when it comes to judging the results of experiments which take place at very low or very high speeds.

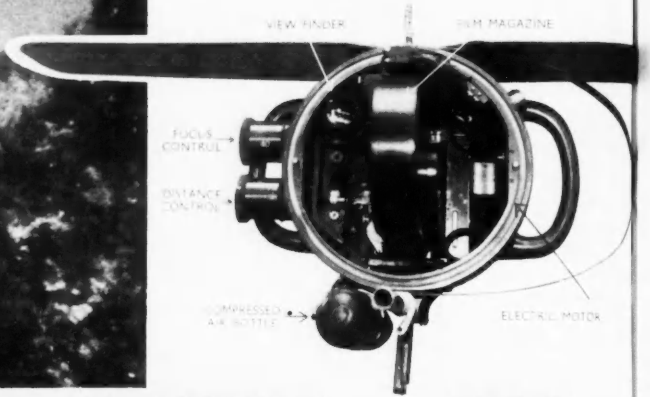
The cine camera has another great advantage; it is able to record transient phenomena, and to preserve a record of them for detailed analysis later on. In addition the cine camera shares with the still camera the advantages offered by the wide range of photographic emulsions available today, and cinematography in the infra-red and ultra-violet zones of the spectrum is now commonplace.

Such are the many advantages offered by the cine camera: how have scientists made use of them?

Ever since it has been possible to take a cine camera on an expedition, it has been used for recording biological, geological and other data. One of the first of such films is also one of the finest ever made; this was the film record of Scott's expedition of the Antarctic in 1911. Shot by H. G. Ponting, it is preserved in the archives of the National Film Library, and provides an outstanding example of high cinematographic achievement under the most adverse conditions of temperature and difficulties of lighting. Ponting used a Williamson camera and hand-cranked every foot of film, and his records of penguins, their breeding habits, and the final emergence of the young bird were unique in his time. Many other explorers have made films since those days. One recalls, for example, Captain S. Noel's work as the official cinematographer on the Mount Everest Expedition in 1927. His task at an altitude of 28,000 ft. was not easy: because of the extremely dry atmosphere, static electricity was liable to leave its mark on the film, while with only occasional breaths of oxygen the sheer mental effort required to start filming must have been almost superhuman.







These pictures show the Aquaflex, a modern underwater cine camera, how it is constructed, and how it is used by an operator wearing a frogman's suit. The camera has an internal exposure meter with an iilluminated dial, and is driven electrically. The internal pressure is maintained at 6 lb. per square inch above the external water pressure, regardless of the depth at which the camera is being used.

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A much more recent Antarctic expedition, known as "Operation High Jump" and made by the U.S. Navy in 1947, had greater foreknowledge of the difficulties to be expected in filming in polar regions. The purpose of this expedition was to find out how a convoy of ordinary ships could operate under conditions of extreme cold and how the personnel carried by these ships could survive a winter in the Antarctic. Sixty-eight photographers accompanied the expedition and during their two months' stay in the Antarctic 240,000 ft. of film were exposed, most of it in cameras mounted in survey aircraft. Some of the material was edited to form the technicolor film called "Operation High Jump" which was widely shown in cinemas in this country; this included the historic record of the discovery of a warm lake in the midst of the Antarctic ice plateau. The operators' difficulties were numerous on the expedition, and although their cameras were tested in refrigerated chambers before sailing, all those that were driven by electric-motors failed at temperatures around -40° F., and had to be hand cranked! (It seems strange that electrical heating equipment had not been fitted, especially since it had already been so successfully used on aircraft cine cameras during the war.)

An altogether different type of expedition, also carried out by the U.S. Navy, was "Operation Cross Roads", which was concerned with the testing of three atomic bombs at Bikini in 1947. 328 cameras were used in all, and 366,000 ft. of film were exposed. Every type of cine camera available to the U.S. Navy was pressed into service; the greatest emphasis was laid on automatic starting of cameras by electronic control, and high-speed records were obtained at 1000 frames per second. The cameras used on the island of Bikini itself had to be heavily insulated against radioactive radiation, the resulting shots of the atomic explosions, which were widely shown in commercial cinemas, were often of terrifying beauty.

An outstanding research film in Geology must be mentioned here: Dr. Pough's record of the Mexican volcano at Paricutin. In conjunction with other geologists he was able to make a film record of the whole life story of this volcano from the first cleavage of the soil, through the gradual growth of the volcanic cone to several thousand feet in the course of a few months, until its present slow cooling off. So much, then, for using film for recording outstanding scientific events and expeditions.

Underwater Cinematography

Underwater cinematography is by no means "an entirely new field of research" as was claimed by the Central Office of Information when it released the film "Wonders of the Deep" (reviewed in DISCOVERY, October 1949, p. 332). The first underwater film that I have been able to trace was produced in 1916 by the Williamson brothers off the shore of Nassau, B.W.I. They used a hollow steel sphere of 5 ft. internal diameter, with a glass window. This sphere was connected by means of a hollow collapsible pipe to the bottom of the boat from which were also suspended an array of lights. This cumbersome affair was later improved on.

Conditions for filming biological events are vastly different when they take place under water and not in air. For instance, the light intensity decreases rapidly as greater depths are reached and water haze confines underwater cinematography to short distances—about 25 ft. is the absolute maximum, for at greater distances the haze becomes too much for effective exposures.

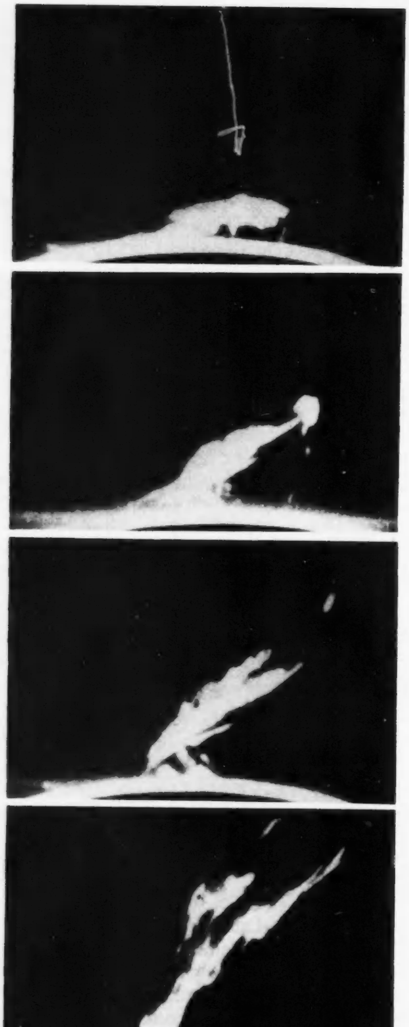
The majority of underwater films have been in the nature of stunts, but scientific interest in underwater cinematography has increased largely because of the example set by Cousteau, who founded the "Club des Scaphandres" in 1935 and stimulated new developments in the technique of underwater cinematography. Light watertight camera cases were constructed, the latest models having fins attached, and as a major advance the clumsy diving suits were dispensed with. The three original inventions of the Divers' Club—the compressed air bottles, the rubber fins attached to the feet and the 'parachute' (a rubber belt which could be inflated in an emergency)—were much used during the war, and they made it possible to employ this type of cinematography for the study of marine biology and underwater phenomena in general. An interesting investigation carried out by means of the underwater camera was the analysis of the turbulence of air and water around a ship's propeller; this was done by J. H. Waddell in 1945 who exposed the film at a rate of 1000 frames per second. There is no doubt that the record of a torpedo leaving a submarine as shown in a recent Admiralty film foreshadows a new use for underwater cinematography. With all the modern equipment now available one hopes to see many more research films on the life histories and habits of marine animals. A great deal of further information on underwater ecology could be gained by using a cine camera. It should be possible with reliable modern equipment to lower into the depths of the ocean automatic cine cameras with light sources attached, and by their use obtain new information about the natural history of deep-sea animals.

High-speed Cinematography

Strictly speaking any speed above the normal—24 frames per second for sound and 16 frames per second for silent films—can be considered as 'slow motion' or 'high-speed cinematography'. Most 16 mm. amateur cine cameras allow speeds up to 64 frames per second, or occasionally up to 70 or 80 frames per second. 35 mm. cameras, as used in commercial studios, go up to about 40 frames per second, and special 35 mm. high speed cameras have been built up to 250 frames per second; this is the limit attainable with intermittent film movement. If higher speeds are required then continuous film movement with optical displacement of the image has to be used.

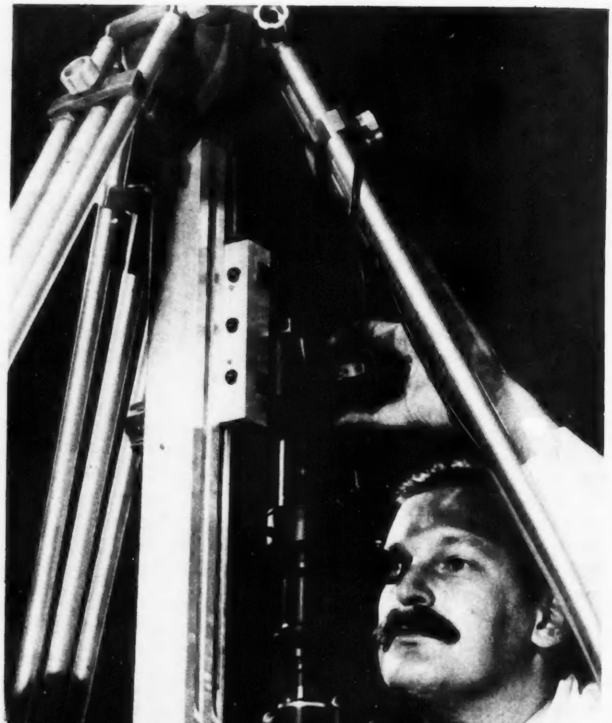
It is not possible here to list all the fields in which high-speed cinematography has been employed, but one or two examples of technological interest may illustrate its usefulness. In chemical engineering, the design of stirrer blades for various types of viscous liquids was carefully studied by G. I. Esselen, who, for example, found the propeller type infinitely better for high viscosity liquids; this fast action could be easily followed on projection of a high-speed film. The stirring of liquids by steady air blasts and intermittent air bubbles was similarly analysed by him. The design of fan blades was greatly helped by this method of time manipulation.

It may be interesting at this point to compare stroboscopic lighting and high-speed cinematography. It is



Frames from a time-lapse motion picture of a solar prominence. They show the development of the great prominence of September 17, 1937, which lasted 80 minutes and was more than 600,000 miles long.
(*Courtesy, McMath-Hulbert Observatory.*)

One of the first important film records of an expedition was that made by H. G. Ponting, seen here with his Williamson camera, who accompanied Scott to the Antarctic in 1911. (*Courtesy, National Film Library.*)



The author's portable apparatus for taking cine pictures is a 35 mm. Cameflex, shown attached to the microscope and held by a specially designed stand.
(*Courtesy, Simpl Ltd.*)

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perfectly possible to obtain with stroboscopic lighting an apparently stationary picture of any given cycle of events. This is, however, a synthesised still which does not show random variations from cycle to cycle. It is not possible to use this method for anything that is self-luminous or for any event that is non-cyclic; both these can, of course, be recorded with high-speed cinematography.

The applications of high-speed cinematography in engineering problems have been listed by Johansen, and include the study of:

(*a*) Mechanisms where quickly moving parts are affected by inertia, elasticity and deflexion; rotating parts which are subject to excessive centripetal or unbalanced forces; vehicles and structures subject to shock or vibration; automatic machine tools, particularly as a method of analysis for faulty operations.

(*b*) The motion study of manual operations is also helped greatly by high-speed cinematography, as well as that of gun mechanisms, projectiles, explosions and rocket flight.

(*c*) Combustion phenomena, flames and flame propagation, as well as visible aero- and hydro-dynamic flow patterns have been analysed in slow motion.

(*d*) Oscillograph records and assemblies of instrument dials showing inter-related rapid fluctuations offer another suitable field for study.

As an unusual example of one of the many possible uses of high-speed cinematography in solving difficult problems one may mention Eyles work on "How does a fly land on the ceiling?" He constructed a glass box (11 × 9 × 9 in.) and, after imprisoning ninety houseflies in the box, smeared the 'ceiling' with honey. A high-speed cine camera was focussed on to the ceiling. The chances of success were small; only one or two landings on the ceiling took place after 1500 ft. of film had been run through the camera, but examination of the film record showed that the fly performed a 'half-roll' in alighting and came to rest at a slight angle to the direction of flight.

Cinemicrography

The combination of microscope and cine camera has by now become a fairly widely used research instrument of biologists and other scientists. It is impossible to give an account of cinemicrography without mentioning the names of Canti, Percy Smith and Comandon, whose pioneering efforts in this field and particularly their work in time-lapse cinematography have led to some very interesting discoveries and to some very beautiful films. The advantages of recording transient phenomena and the possibility of time-lapse work are now universally recognised. This latter has proved of great value when the slow growth of cells is under investigation; using phase contrast microscopy, Hughes in this country and K. Michel in Germany have succeeded in filming the process of cell division in remarkable detail. Hughes recorded the process of mitosis on film taking exposures at about 10 seconds interval and projected them at normal speeds, with an optical magnification of 2200.

An entirely different type of film record was made when the process of baking a cake was scientifically studied in the microbaking oven. Considerable technical difficulties were encountered when it came to record these experiments on colour film. The cake had to be thin enough to be transparent, the experimental oven had to be specially constructed, and the ingredients had to be dyed differentially (e.g. flour was dyed purple with iodine). It was found that the air cells so necessary for successful results were only present in the shortening and in no other portion of the batter. Using polarised light as a source of illumination, it was found possible to watch the progress of the baking and to determine the end of the baking process by watching for the extinction of the cross marking each wheat-flour starch grain.

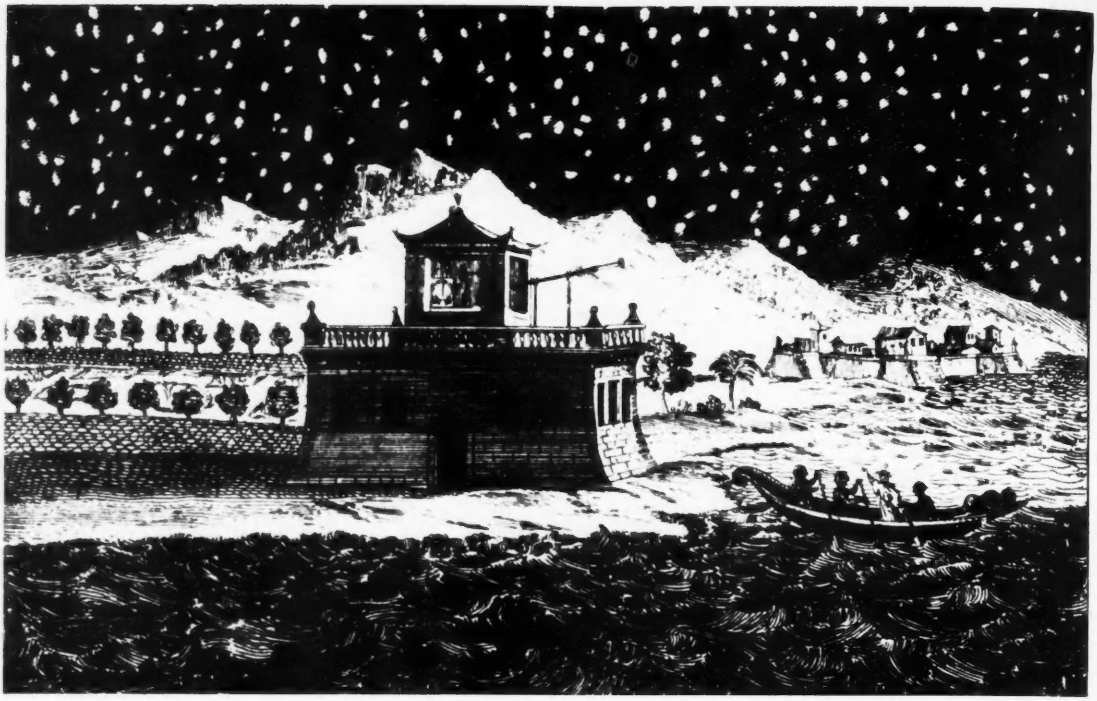
A very interesting research problem, the motility of typhoid bacteria, was investigated by Prof. Pijper with the aid of cinemicrography. In his films the movements are clear and show that each bacteria has two flagella attached near the middle of its body, and that these are wound like a corkscrew; in motion, they turn around their own axis, this revolving motion being communicated to the body of the bacteria which is pushed forward at the same time.

At first sight it seems improbable that cinematography could help to solve the many problems that confront the astronomer. The exposure times required for ordinary photographs in astronomical work are long enough, and lighting requirements for cinematography are notoriously higher than for ordinary still camera work. Time-lapse work has helped here to clarify some of the sights seen through the telescope in much the same way as those seen through the microscope.

The problem of photographing the sun's corona has always been the aim of astronomers. It used to be possible to do this only at the time of total eclipses and for this purpose expeditions have gone far afield, as Jansen did in 1875. The use of the spectro-heliograph was an advance to obtain the same results without an eclipse. This instrument allows photographs of the sun to be taken in one particular wavelength of the spectrum only. The sun's image is formed on the slit of a spectograph and a second slit is placed before the photographic plate. The movement of these two slits allows the corona to become visible on the plate and showed the existence of large prominences. Lyot and Menzel developed the instrument, which they called the Spectro-helio-kinemato-graph, to such an extent that a cine film could replace the photographic plate, and it became possible by using time-lapse cinematography to record the movements of these enormous prominences over a period of many hours. These films have raised many new problems in the mind of the astronomer.

The few examples I have given indicate what use has been made of cinematography in scientific research.

The Sciences Committee of the Scientific Film Association in this country, which was responsible for organising the Conference at the Royal Institution in October 1948 dealing with this subject, is anxious to hear from any scientist who is using a cine camera as a research tool. The Committee has decided to collect references to published work and to compile a register of scientists working in this field. The aim of this register is to help those who have had no previous experience with cine cameras to contact more experienced workers in this field, and any information supplied will be treated as strictly confidential if so desired. The address is 4 Great Russell Street, London, W.C.1., and from it can be obtained further details of any of the researches described above.



A drawing of the astronomical observatory at Cape Town used by Père Gui Tachard in 1685.

Science in South Africa

H. B. S. COOKE, F.R.S.S.Af.

In 1483, the Portuguese sailor Diogo Cão reached the mouth of the Congo and five years later Bartholomew Dias rounded the southern tip of Africa (with the aid of a storm) and was the first European to set foot upon the south coast of the continent. South Africa became known to Europe four years before Columbus discovered the New World but no settlement was created until 1652 when the Dutch East India Company sent Jan van Riebeeck to establish, at the Cape of Good Hope, a southern station of the Company for the revictualling of ships.

Although the Portuguese and other sailors using the new trade route to the East had collected a certain amount of information about the southern part of Africa, it was not until the settlement at the Cape was firmly established and became a regular calling point for ships that any real scientific work could be accomplished. As early as 1685 an expedition set out to visit a copper area, 250 miles to the north, which had been reported by the aboriginal inhabitants—little brown men known as Hottentots and Bushmen—and this expedition brought back the first information about the interior. Almost a century was to elapse before as long a journey was undertaken again.

When the first hundred Dutch settlers landed at the Cape, they found the mountains rich in beautiful flowers of great variety and the plains teeming with wild animals of many kinds. Plants were taken to Europe for cultivation there and, indeed, Europe owes many of its fine cultivated plants to the Cape. Amongst these may be mentioned the Pelargoniums (which most people wrongly call 'geraniums'), the lovely Belladonna Lily (*Amaryllis*), the white Arum Lily, some Gladioli and many Irises. Some of these plants were so well known in Europe that their place of origin was actually forgotten by the early classifiers as is shown, for instance, by the fact that the Cape *Nerine sarniensis* was called the Jersey Lily and the typically South African *Aloe soccotrina* was believed to come from Sokotra in the Gulf of Aden!

Many eminent scholars and scientists from Europe called at the Cape on their way to or from the East and some stayed there for short periods. It was not, however, until the latter half of the eighteenth century, when more of the amenities of civilisation were available, that scientific workers began to use Cape Town as a base. Many naturalists came to collect animals and plants for study in Europe and amongst them were Sparrmann and Thunberg from the school of the great Linnaeus, whose interest had been aroused through specimens sent to Sweden by the Governor of the Cape, Ryk Tulbagh. During this period, too, the Abbé de la Caille carried out the first systematic astronomical work to be undertaken in the southern hemisphere and

his compatriot, le Vaillant, made the first significant contribution to bird studies south of the Equator.

The officer in command of the garrison at the Cape, Colonel Robert Gordon (a Dutchman of Scots ancestry) undertook many exploratory trips into the interior and left most valuable pictorial records of what he saw. He discovered the Orange River, naming it after the Royal House of Holland. His fine maps, which included much information gained from aboriginals beyond the limits of his travels, formed a valuable basis for the journeys of later scientists and explorers.

When the Cape finally became British territory at the beginning of the nineteenth century, there was a fresh stimulus given to scientific field work and by the middle of the nineteenth century the geography and natural history of southern Africa were broadly known.

First Local Developments

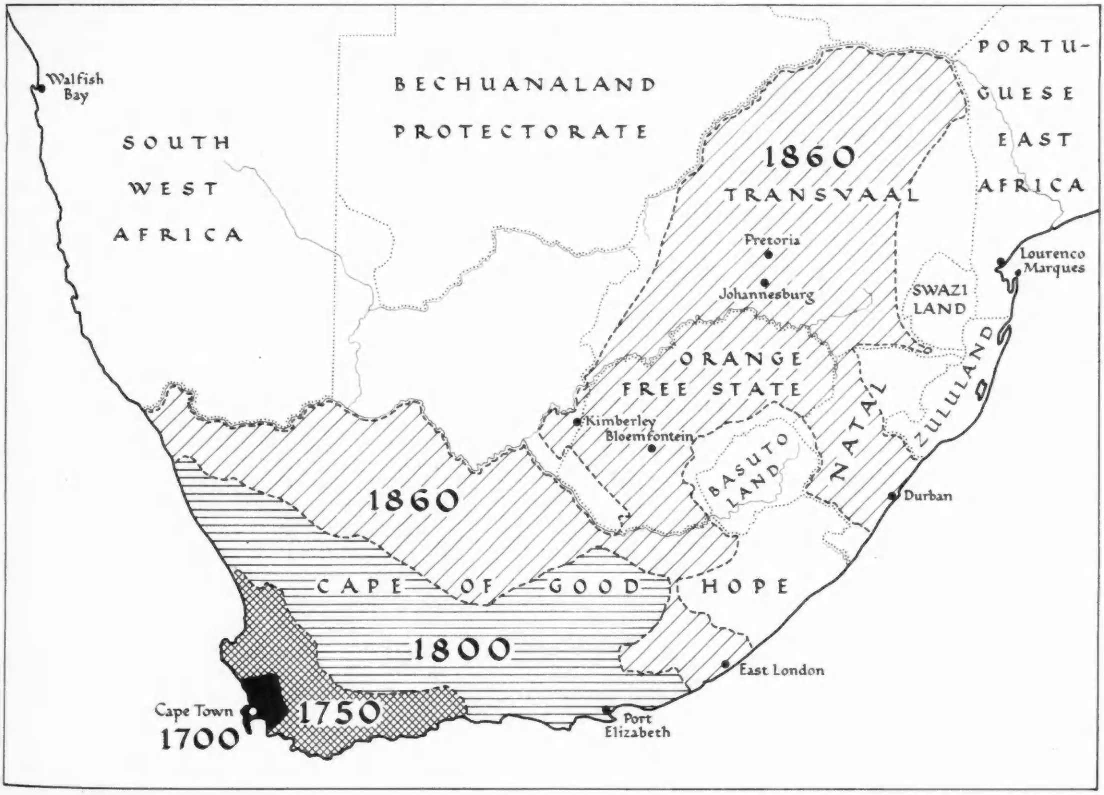
In the absence of local facilities, the visiting scientists took back to Europe for study and description all the material they collected. By 1820 the Colony covered some one hundred thousand square miles of country (about the area of the British Isles) and the majority of the forty-five thousand white inhabitants lived in or around Cape Town, where the first sparks of local interest in science appeared during the 1820s.

It was in 1820 that the Lords of the Admiralty decided to establish an observatory at Cape Town and in the following year the Reverend Fearon Fallows arrived to set up the Royal Observatory. He helped to stimulate a local interest in scientific matters and may have been partly instrumental in inducing the Governor, Lord Charles Somerset, to sanction the founding of the South African Museum in 1825 with a physician, Dr. (later Sir) Andrew Smith, as its first Superintendent.

At about the same time, a Scientific Institution and a Literary Society were founded, later becoming the South African Literary and Scientific Institution. The *Quarterly Journal* of the Institution, which began publication in 1829, was the first scientific periodical to be published in the country. Unfortunately it died five years later and the Institution faded away in the middle of the century. Apart from helping visiting scientists the Institution made it possible for Dr. Andrew Smith to undertake a valuable scientific expedition into the interior. Smith was a great enthusiast but after he left the Colony, in 1837, the museum collections were neglected and the museum slowly disintegrated.

The rise and fall of these early scientific bodies is a clear indication of the dependence of science, at this time, upon the initiative of a few enthusiastic individuals. The creation of these bodies was one expression of a need which was felt locally at the time, but the country was not then ripe for

The expanding frontiers of European occupation in South Africa.

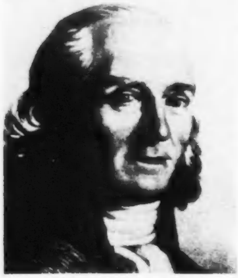


societies or institutions and they failed to survive. In the field of higher education the South African College began its career at the Cape in 1829 with three professors and a hundred students. It rose slowly to the level of university instruction but it was not until 1873 that a "University of the Cape of Good Hope" was established, without teaching functions but with powers to confer degrees by examination. The South African College, and several similar bodies which had come into being in the expanding colony, provided the teaching.

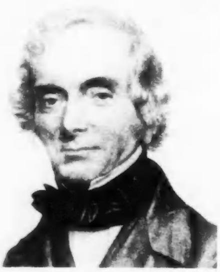
The brief burst of scientific enthusiasm in the 1820s was followed by a period of eclipse in local scientific efforts which lasted until well into the latter half of the century. In 1855 the South African Museum was founded afresh. The eastern Cape, which was becoming well settled under a British immigration scheme, founded two museums within a year and by the turn of the century there were seven museums in various parts of South Africa, including two in the Dutch republican territories of the Orange Free State and the Transvaal. This time there was no retrogression and it may be said that the refounding of the South African Museum marked the real beginning of scientific development within the country.

The growing interest in science was also manifest in the springing up of a number of local scientific societies in the latter part of the nineteenth century but it was not until relatively late that any bodies of wider significance were established. In 1877, the South African Philosophical Society was founded in Cape Town. It soon grew in importance and later became the Royal Society of South Africa—the senior scientific society in the country today.

Various specialist societies grew slowly during the early part of the twentieth century, absorbing the smaller local bodies, but even today there are a number of sciences which rely upon the broader bodies such as the Royal Society of South Africa and the South African Association for the Advancement of Science (1902) to provide an outlet for discussion of their subjects and media for publication. (South Africa, whose white population has not yet reached two and a half millions, must still be regarded as a developing country whose preoccupation with immediate practical problems must, to some extent, hamper progress in many branches of 'pure' research).



Carl Peter Thunberg.



William J. Burchell.

Sir Andrew Smith.

Sir David Gill.

Astronomy and Geodesy

Once long ocean voyages began in the southern hemisphere, it was obvious that more must be learned about the stars of the south as an aid to navigation. It was important that the true position of the Cape should be known as accurately as possible and so, even before the settlement was established there, astronomical observations were made at or near the present site of Cape Town. In 1685, a French mathematician and Jesuit priest, Père Gui Tachard, spent a few days at the Cape on his way to Siam and there set up a twelve-foot telescope in a temporary observatory. He determined the longitude with a greater accuracy than had been achieved before and he recorded the fact that the star at the foot of the Southern Cross (Alpha Crucis) was a double star.

Other sporadic astronomical observations were made at the Cape but the first serious programme to be undertaken was that of another French priest, the Abbé de la Caille, who landed in 1751 and stayed for two years. He catalogued over ten thousand stars and named many constellations including 'Mons Mensae', after the famous Table Mountain of the Cape. The energetic Abbé also started the first geodetic work in southern Africa by setting out a short arc of meridian, one and a quarter degrees in length, north of Cape Town. His choice of the Cape as an observation point was doubtless due largely to the fact that Cape Town, small as it was, was then the biggest town in a good southerly latitude and thus offered the best general facilities available at the time.

To a lesser extent, this consideration probably influenced the choice of the Cape as the site for the Royal Observatory. The first Royal Astronomer died three years after the installation of the equipment had been completed and his successor, Thomas Henderson, worked at the observatory for little more than a year. During that short time, however, he made a catalogue of the principal southern stars as accurate as the best star catalogues of the northern hemisphere. The Cape Catalogues begun in 1840 still provide much of the best information available on southern star positions, proper motions and the like.

In 1834 Sir John Herschel arrived on a private mission to the Cape with an 18-inch reflecting telescope, which he set up and used for four years in cataloguing the southern nebulae and double stars. He also did some work at the Royal Observatory and helped in revising the backward educational system of the Colony.

In 1879, the post of His Majesty's Astronomer at the Cape was filled by Sir David Gill. It was largely due to Gill's inspiration that photography came to be used in charting the skies and in determining the proper motions of stars. The photographic survey which he began and, which was completed by his successors in 1927, is of fundamental importance in southern hemisphere astronomy.

Sir David Gill, like his immediate predecessor Sir Thomas

(*Right*)—THE SOUTHERN CROSS.

Maclear, and also the Abbé de la Caille, interested himself in the earth as well as the heavens. He laid the foundations for an excellent system of geodetic chains to form a basis for topographic and other surveys in South Africa and also started a scheme for the measurement of an arc of the thirtieth Meridian from southern Natal to the Mediterranean. This great concept is today within sight of completion and will eventually link with Struve's great arc of meridian which ends in latitude 70° north.

The fine clear skies of the interior of South Africa are ideal for astronomical observations and today there are seven observatories (all established since 1900). They have a wide variety of equipment including a 60-inch reflector in the Boyden (Harvard) station at Bloemfontein and a 74-inch reflector at the Radcliffe Observatory in Pretoria. This 74-inch telescope (described in DISCOVERY, August 1948) is the biggest telescope in the southern hemisphere.

Astronomers in South Africa have had an outstanding record in making new discoveries. Local amateurs have an unusual flair for finding comets and it was an amateur who first observed the famous 'split star' Nova Pictoris. Dr. T. A. Innes, of the national Union Observatory, found and measured the distance of the star nearest to our own sun which he named Proxima Centauri. Dr. Innes became famous also for his work on double stars and the Union Observatory has continued under his successor to pay particular attention to this branch of astronomy.

Physics and Geophysics

Along with astronomy, meteorology received early attention. Systematic weather observations started at the Royal Observatory in 1841 but it was not until 1874 that a network of observing stations began to take shape under the newly created Cape Meteorological Commission.

A very remarkable pioneer in this field in South Africa was Dr. J. G. Sutton who, in 1886, took charge of a well-equipped private meteorological station financed by the De Beers diamond mines at Kimberley. He published many outstanding papers and was described by one eminent German authority as "the greatest of all amateur meteorologists." Today, meteorological research is being undertaken by the Government Weather Bureau which has made encouraging progress towards the objective of long range forecasting.

Thunderstorms are very frequent in southern Africa; Johannesburg and Pretoria, for example, experience seventy to eighty separate storms each summer. Not unexpectedly South Africa has one of the most vigorous schools of thunderstorm research, founded by a South African-born physicist, Dr. B. F. J. Schonland.

The Bernard Price Institute for Geophysical Research, of which Schonland is the Director, is interested also in many other problems, including studies of the frequent minor earth tremors associated with the gold mining area of the Witwatersrand. The Witwatersrand tremors have recently been used in researches designed to determine the depth of the granite layer of the earth's crust in this region and the thickness and nature of the overlying layers of sedimentary rocks. The method is virtually an extension of the techniques employed in seismic prospecting for oil and other mineral deposits, the natural tremors, which on the Witwatersrand occur about fifteen times a week, taking the place of artificial explosions. The energy of an average tremor is about equal to that which would be produced by fifty tons of dynamite and records are being made at distances up to four hundred miles from the source.

The Bernard Price Institute for Geophysical Research is not, of course, the only body undertaking geophysical or physical research. Amongst the many others may be mentioned the National Physical Laboratory of the South African Council for Scientific and Industrial Research, the Universities and some Government departments. A Magnetic Observatory, situated at Hermanus, about seventy miles east of Cape Town, makes continuous observations of the declination, vertical and horizontal intensity of the earth's magnetic field and also undertakes periodic surveys by making sets of observations at about fifty stations scattered over South Africa, South-west Africa and Bechuanaland. It is interesting to note that there are records of occasional determinations of the deviation of the compass needle at the Cape from the late sixteenth century to the present day. (*To be concluded in the May issue.*)

A Late Bronze-Age Village in Sussex

G. P. BURSTOW, F.S.A.

PREHISTORIC man found the light soil of Britain's South Downs particularly suitable for his agriculture, and the remains of his dwelling-places are common on their slopes. So rich is the county in ancient sites of all periods that the Research Committee of the Sussex Archaeological Society has decided to specialise for the next few years in one period, and has chosen the Late Bronze Age (1000–500 B.C.) for study. The outward signs of Late Bronze Age settlements are groups of small irregularly shaped enclosures with low earth banks, each containing one or more small circular huts. The walls of these were built of wood which has long since decayed, but on excavation the post-holes, both of walls and centre post, remain clearly discernible in the white natural chalk. The settlements must have presented much the same appearance as many African native villages do today.

Several of these sites were partially excavated before the war, and much information has been collected about the history of the people who occupied the villages and their mode of life. Eight of their hut-sites on Park Brow to the north-east of Cissbury, and an enclosed farmstead on Newbarn Down, near Worthing, have been examined, and a similar hut-site is being excavated on a spur of Blackpatch across the valley from Newbarn Down. Post-holes and a cooking floor of the period were found under the Iron Age ramparts of Highdown Hill, near Ferring. Other similar sites probably existed on Castle Hill, Newhaven and at Kingston Buci where much pottery has been found. The excavation of the upper site at Plumpton Plain near Ditchling in 1934, where a double-lynchet road winds among the enclosures, proved for the first time that people of the earlier phase of the Bronze Age (1000–750 B.C.) cultivated some of the small rectangular fields whose lynchets or boundaries are so clearly visible on the open downland today. A settled agriculture had at last come to Britain.

Just before the war Mr. G. A. Holleyman, F.S.A., my partner in directing the subsequent excavations, came upon a group of such enclosures on Itford Hill, a mile or so north of Newhaven. Ancient field boundaries cover the hillside, though we were not able in this instance to prove their association with the settlement. The Brighton and Hove Archaeological Society decided to strip the whole site in the course of the next few years, and commenced their work in August 1949, incidently their first season's digging since the war. Part of the largest enclosure was selected which seemed from surface indications to contain four hut-sites. So far three of these have been uncovered, and a large part of a yard in front which was bounded by a line of post-holes.

The centre hut, 22 feet in diameter, was probably a dwelling hut, though no sign of a hearth was found. It was entered through a porch rather in the style of a modern army hut, by the side of which appeared one of the most interesting finds of the site, a carved chalk phallus resting in an upright position. This indicates one form of the religion of these people, a cult to promote the fertility of their cattle or crops, such as has been noted in many peasant communities from Neolithic to modern times. The Neolithic sites on the Trundle and Whitehawk in Sussex have yielded similar objects, made in bone, but as far as we know this carved chalk specimen is the first to be found on a Late Bronze Age settlement site in this country.

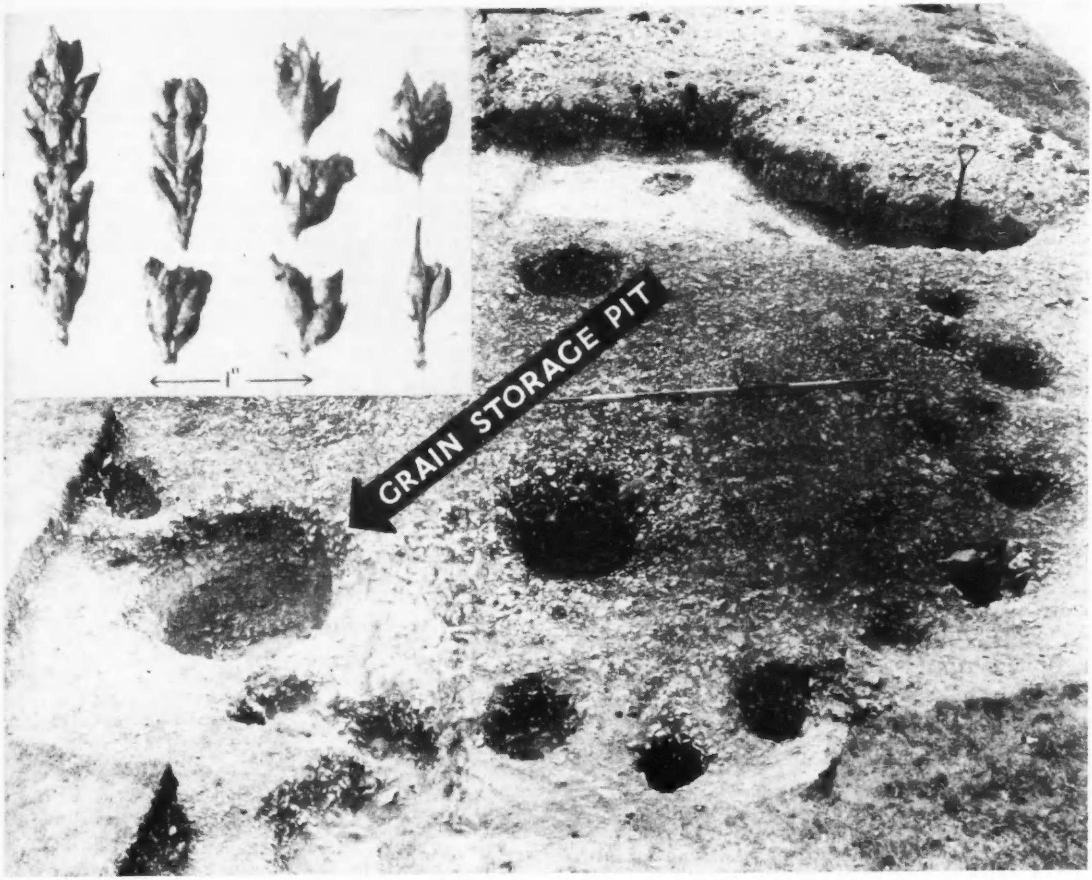
The eastern hut-site had been rebuilt in ancient times. Two series of post-holes adjacent to each other, were found, one set filled in with tightly packed flints, forming a circle about 18 feet in diameter. This hut contained two storage pits, from one of which came the spectacular find of eleven and a half pounds of carbonised grain. This included several ears of corn which we were able to photograph before disintegration. The grain lay in the shape of a cone at the bottom of the pit.

A sample of this grain has been sent to Denmark for detailed study, along with the dust associated with it which may be expected to contain seeds of the weeds that grew with the corn. The results we hope will give information not only about the type of grain used by these primitive farmers, but also tell us something about the climatic conditions of their times. In the storage pits were also found the upper and lower stone of a saddle quern, the handmill of Late Bronze Age times.

On the floors of the huts appeared numerous fragments of cylindrical clay loom-weights, showing that the inhabitants did not rely entirely on skins for clothing but produced a form of cloth. At Itford no spindle whorls were found though these were common on the later site at Plumpton Plain. The smallest hut, only half of whose circumference was surrounded by deep post-holes, was 15 feet in diameter, and had a series of smaller holes inside, which may well have held posts for tethering animals. Pottery and broken loom-weights were found in the hut.

Fragments of pottery were frequent over the area of the hut-sites, though they were scarce in the farm-yard. The pottery was all crudely made of baked clay, and impregnated with flint-grit; sometimes it was ornamented with finger-tip or jab ornament either on a raised band or on the body of the pot. Many of the vessels though not identical showed the influence of the Deverel-Rimbury people (so-called after the Wessex sites where their culture was first recognised), who came to this country in the eighth century B.C. and left behind distinctive pottery, barrel-shaped runs with raised bands and finger-impressions, in their cemeteries. Very recently one of their cemeteries has been found in a ploughed field on Steyning Round Hill, and this contained a collared urn which survived from the Middle Bronze Age, besides Deverel-Rimbury ware.

In the years between 1000 and 500 B.C. a series of peaceful agricultural communities began to infiltrate into Britain from the Continent. About 1000 B.C. a people from Central Europe moved across the Rhine, and pushed out some of the French Middle Bronze Age natives to southern Britain. These brought with them a distinctive pottery, globular urns which we find on the older of the Plumpton Plain sites, at Park Brow, and probably in the



The site of a late Bronze-Age hut on Itford Hill, Sussex. The ring of holes corresponding to the posts that supported the walls is seen, and also the centre post-hole. The storage pit is labelled; this contained eleven and a half pounds of grain which had become changed into carbon, as happens naturally to all seeds stored for very long periods. (*Inset*) Ears of corn from the storage pit. (*Both photos by N. E. S. Norris.*)

newly discovered cemetery at Steyning. In the eighth century the Deverel-Rimbury people came over from the Continent and colonised regions in southern England, mainly Hampshire, Wessex and Kent. Later a people whose culture was derived from the West Alps travelled up the continental rivers into Northern France and thence came to Britain, to influence the culture of the later site at Plumpton Plain (750–500 B.C.). All these newcomers modified the original tradition of the Middle Bronze Age pottery. Then in the sixth century B.C. the influence of an Iron Age people (whose type site is the great cemetery at Hallstatt in Austria), who were developing pottery with a pronounced shoulder, arrived to modify the already complicated pottery tradition; these were the warrior peoples who eventually reached southern Britain about 500 B.C. and overthrew the peaceful agricultural communities of the Bronze Age.

How does the Itford site fit into this context? We found no pottery directly comparable to the French ware of 1000 B.C., or the West Alpine or yet the Hallstatt. The pottery does, however, show a Deverel-Rimbury influence in shape and ornament, and I do not think we shall be far wrong in assigning the huts we have excavated to the middle period of the five hundred years between 1000 and 500 B.C.

Our work has enabled us to add something to the knowledge of the Late Bronze Age peoples whose settled agricultural economy prepared the way for the civilisations which followed. As G. M. Trevelyan remarks in his *History of England*, "Agriculture is the greatest change of all in the early life of man, for it enables him to multiply, fixes him to the home and to the soil, draws him into larger village communities, and thereby renders other inventions and changes more easy."

The Military College of Science

THE Military College of Science, now established at Shrivenham as the 'Science University' of the British Army, had a beginning which like that of our most venerable institutions is somewhat obscure. Perhaps its most natural starting point is the year 1772, when two young gunnery officers, E. Williams and A. Jardine, founded the Military Society of Woolwich for the theoretical, practical and experimental study of gunnery. Unfortunately, owing to the exigencies of war, the young society was swept away eight years later though it succeeded in creating a tradition which never quite died.

During the early part of the nineteenth century, the scientific ideal was preserved by Army officers like Major-General W. Mudge, General Sir H. Douglas, F.R.S., and General Sir E. Sabine—the latter attained the distinction of becoming President of the Royal Society.

As a result, in the late '30's, two of these officers, Major-General F. M. Eardley-Wilmot and General Sir J. H. Lefroy (both of whom eventually became F.R.S.'s) proposed the creation of an institution for the study of science and modern languages. This proposal was favourably received and in 1840 the Royal Artillery Institution at Woolwich was established. Unfortunately it had to be supported mainly by voluntary means so that its continued existence was precarious, but ten years later the War Office decided to afford it official recognition and made a more liberal grant of public money for the carrying on of the instruction of gunnery officers, and by the creation of the post of Director of Artillery Studies.

It soon became evident that with the possibility of great changes in artillery, the acquisition of the scientific knowledge a gunnery officer needed could not be attained by short courses attended by a few volunteers. A proposal to establish a special longer course was therefore put forward by Lefroy (then Secretary of the Ordnance Committee), Major C. F. Young (Director of Artillery Studies) and Major C. H. Owen (Professor of Artillery at the Royal Military Academy). In 1864 the Advanced Class for Artillery Officers came into being; after the new two-year course successful students were granted a certificate of having "passed the advanced class" together with the right to use the letters 'p.a.c.' after their names. This course was conducted under the control of the Director of Artillery Studies and instruction was provided in a wide range of scientific and 'professional' subjects; the former included Mathematics, Chemistry, Physics and Metallurgy. The teaching staff was at first quite small and comprised only three men: Rev. F. Bashforth (Professor of Applied Mathematics), Major C. F. Young R.A. (Director of Artillery Studies), Capt. Brackenbury R.A. (Assistant Director). There were in addition lectures by visiting scientists, including Dr. J. Percy, F.R.S. (Professor of Metallurgy at the Royal School of Mines), Prof. T. M. Goodeve, and Mr. C. L. Bloxarn. If the visiting lecturers were few they were all distinguished in their own field; Bashforth, for example, had long been famous for his work on ballistics, Percy was equally well known in connexion with metallurgy.

In 1885, a major development occurred when the establishment was transferred to more spacious accommodation in a part of Red Barracks, Woolwich and received the official name of 'Artillery College'. For some unknown reason, the name of the College was changed in 1899 to that of 'Ordnance College'.

During the latter part of the nineteenth and the early part of the twentieth centuries the permanent staff of the College gradually increased. Professorships in Chemistry and Electrical Engineering were created, the former being filled by Professor W. R. E. Hodgkinson, F.R.S.E. A worthy successor to Bashforth had been found in A. G. (Later Sir George) Greenhill, F.R.S. who held the professorship of Gunnery and Mathematics for thirty-one years. The so-called 'professional' branches were staffed by military instructors, many of whom were p.a.c.'s.

At the beginning of World War I, the unfortunate decision was made to close the College, a decision only to be reversed in 1917 by the increasing need for officers of the p.a.c. type. After the war was over, its fate hung for some time in the balance but eventually the decision was made in its favour and a new era opened in its history. The curriculum became more strictly scientific and there was an increase in the number of professors to four by the establishment of a Professor of Physics, a position eminently filled by Professor E. N. da C. Andrade, F.R.S., whilst that of Electrical Engineering was combined to cover Mechanical Engineering also, the first holder of the combined appointment being Professor J. J. Guest. Owing to retirement, the other two professorships had also become vacant; that of Mathematics was filled by Professor H. C. Plummer, F.R.S., who had previously been Astronomer Royal of Ireland and that of Chemistry and Metallurgy, by Professor K. C. Browning. These four formed a very strong team and much is due to them for all that happened in the subsequent years. The College ceased to be completely, or almost completely, a gunnery stronghold and an indication of this was given by again changing its name in 1927 to the Military College of Science, which it still retains.

In 1939, with the outbreak of war, the College was first evacuated to Lydd, Kent and thence in 1940 in part to Bury, Lancs., and in part to Stoke-on-Trent, losing in the process its senior civilian scientific staff. These two units concentrated during the rest of the war on instruction in the science and technology of fire-control instruments and weapons respectively; a third unit came into being at Chobham in Surrey in 1942 to do the same for tanks.

Since the War

Finally in 1946 the three separate units were recombined in a new home at Shrivenham, near Swindon, and the College received a new character which gave it the role of educating officers in science and technology and of training them to apply their military knowledge and experience to the problems of the modern war.

It is now divided into four Faculties, comprising Mathematical Physics, Chemistry, Mechanical Engineering, and Instrument Technology. Each Faculty is made up of groups of Branches dealing with the more specialised aspects of the general subjects; thus the Mathematical Physics Faculty consists of three Branches—Mathematics, Ballistics and Physics; the Chemistry Faculty of three Branches—Chemistry, Applied Chemistry and Metallurgy; the Instrument Technology Faculty of three Branches—Electrical Engineering, Radar and Telecommunications, and Engineering Physics. Each Faculty is controlled by a Professor and the staffs of the Branches are civilian. The head of the College is the Commandant (with the rank of Major-General) and he is assisted by the Dean who is head of the academic staff. The present Dean is Sir Reginald Stradling, F.R.S. To cover the more military aspects of instruction there are three Military Directors of Studies each of whom has a small staff of Technical Staff Officers. They carry on the instruction given by the Faculties, applying the principles and examples to military requirements.

Courses at the College

There are three main courses at the College, Firstly there is the Technical Staff Officers' course, which is really a development of the older Advanced Class and is designed for officers between the ages of 27 and 32, who must have a minimum of five years' regimental service. A qualifying examination has to be passed, the standard of which is about equivalent to Inter B.Sc., in Mathematics, Physics, Chemistry and Applied Mathematics. The first year of the course is designed to increase and broaden their academic knowledge. Thus the first year syllabus is devoted about half to the fundamental sciences, and about half to mechanical and electrical engineering, covering also metallurgy, drawing, electronics and a short course of production engineering. In the second year the student is allowed to specialise to a limited extent. Whilst it might be considered an ideal to train an individual in pure and applied science to the extent that he should have a scientific background that he could apply to the complete range of war material, such an achievement is not possible nor probably desirable. Such a broad education would, in the time available, necessarily be also a shallow one. The student, therefore, selects one of three fields for specialisation—weapons, fighting vehicles, or instruments. In

Students learning techniques for testing oils in the Fuels and Lubricants laboratory.

fact, these three groups overlap, and the student, having a choice of major and subsidiary subjects, does in practice cover one group of subjects as his primary choice and a second or part of a second group as his secondary choice; as an example, a student who chooses fighting vehicles will study the construction of hulls and chassis of tracked and wheeled vehicles, transmission suspension and steering systems and the power unit, but he will also study either the principles of guns and small arms and their mountings, or the principles of wireless and electrical control systems, which whilst forming part of the instruction of the other groups, are directly associated with the study of his own. The syllabus therefore continues to be fairly broad, and is confined to principles.

In addition to the studies mentioned above, the Technical Staff Course student must increase his general military knowledge and gain practical experience of workshop methods. During his two-year course he spends ten weeks in the workshops at Loughborough College.

The Young Officers Course.—Officers of the Army's technical corps (Royal Engineers, Royal Corps of Signals and Royal Electrical and Mechanical Engineers) need a knowledge of either Civil or Mechanical and Electrical Engineering, and consequently it was decided that the most appropriate training for such officers was that offered by the B.Sc. (Engineering) degree course of London University. At the same time it was realised that for a proper balance some officers should be trained for a General Science Degree. Young Officers are therefore taught the subject matter covered by London University syllabuses of these degrees, and the College is recognised by the University for this purpose. This course is taken by cadets who have passed their Inter. B.Sc. at the Royal Military College, Sandhurst and done two years' regimental service. About 15% are allowed to choose the General Science degree; the remainder take Engineering degrees. In accordance with the intention of raising the standard of the whole army, this course is not restricted to officers of the Technical Corps, but is open to officers of any arm.

Post-Graduate Courses.—The Technical Staff Officer receives only a broad education and is in no way a 'specialist'. There is, however, sometimes a need for officers, or perhaps for scientists or engineers employed in the Ministry of Supply, to have short courses to assist them to specialise on some detail of development. These courses are arranged at the College when the demand arises and as staff are available for instruction. The courses themselves are for small numbers and vary in length according to the subject.

Research

It is the intention that the staff of the College shall have ample time for research as in a normal university, and of recent years a considerable amount of research has been carried out at the College in meteorology, pure and applied mathematics, rockets, physics, hydraulics, chemistry and metallurgy, servo mechanisms and computing devices.

In conclusion it may be added that the College possesses most of the amenities of a modern university. It is also extremely fortunate in being near Oxford University, members of which have co-operated with the staff of the College in a most helpful manner.

Air-borne bacteria can destroy penicillin and elaborate precautions are taken in the factory to keep them away from the drug. The photo shows ampoules of penicillin being stoppered; the air in the room is kept sterile by means of tubular ultra-violet lamps. (*Distillers Company photo.*)

Ultra-Violet Light in Industry

J. A. RADLEY, M.Sc., F.R.I.C.

It is common knowledge today that white light can, by means of suitable prisms and lenses, be broken down into its constituent colours which range through violet, indigo, blue, green, yellow and orange, to red. The light of any particular colour is distinguished from the others in the same way as the notes of a piano are distinguished, *i.e.* they have different wavelengths. Violet light has a shorter wavelength than indigo, and this, in turn, is shorter than blue, and so on, so that the red has the longest wavelength of the visible colours.

Below the visible red radiation comes still longer and longer wavelengths, the infra-red right down to short-wave radio waves. Again, at the other end of the scale, we have waves with wavelengths shorter than the violet, the so-called 'ultra-violet' rays; still further along the scale come the radiations with still shorter wavelengths, and which range through the various soft and hard X-rays to cosmic rays.

Most people are aware of the tonic quality of sunlight which has been ascribed by physicians by the presence in the sun's rays of ultra-light, and working on this principle, manufacturers have produced for many years lamps which give out intense ultra-violet light for various medical and therapeutic uses, and to provide artificial sunlight for indoor 'sun-bathing'. It is not generally realised, however, that ultra-violet radiation is widely used in industry for the production of a large number of effects not easily obtained by any other means; that by its use tests can be carried out in a large number of industries on the quality of products and raw materials, and that it can be used for the protection of foodstuffs from many airborne moulds and bacteria, and to kill the airborne 'germs' that cause human diseases.

The sun is the natural, but very uncertain, supplier of ultra-violet light, whilst an overrun electric lamp bulb also gives out an appreciable quantity. Certain mixtures of gases give flames which radiate ultra-violet light, but these sources are expensive and inefficient. The most favoured source nowadays is the high-pressure mercury arc discharge lamp. This is a transparent quartz tube having special electrodes at either end, and containing a small globule of mercury. On passing an electric current, the mercury vapour present acts as a conductor, and at the same time gives out radiation, much of it in the ultra-violet region.

The tube is made of quartz because this offers little or no resistance to ultra-violet light, whereas a glass would absorb an appreciable quantity.

When considering the uses of these rays in industry, the first to be considered may be termed the 'photo-chemical reactions', i.e. chemical reactions which are induced by irradiation to proceed in a manner which renders the operation a commercial proposition, and which otherwise would progress so slowly as to be useless commercially. Mention may be made of the reaction between naphthalene and chlorine gas to give chloronaphthalene, a chemical of some industrial importance, which is readily carried out when the reactants are illuminated by ultra-violet radiation.

In a number of industries it is very desirable to cause the molecules of a substance to combine with each other in order to form a product with entirely different properties; this is called 'polymerisation'. Thus some gases and a number of liquids will 'polymerise' to form solids which have desirable properties for certain purposes. One example is in the manufacture of patent leather; a suitable liquid varnish is applied to the leather which is then exposed to batteries of mercury arc lamps, the radiation from which causes the coating to polymerise to the familiar flexible surface so characteristic of patent leather.

The gun turrets and other similar structures on aircraft are commonly made from the plastic known as 'Perspex', which has superb optical properties. Now, if a join is made by cementing two transparent surfaces together, the cement is likely to differ in optical properties from the material that is being joined, so that perfect transparency and optical clearness is not obtained at the joint. The problem, then, in producing Perspex 'blisters' for aircraft work was to find a suitable means of joining the prefabricated sections of the plastic in such a way that the join did not interfere with the almost perfect optical properties of the material. This problem was solved by using liquid Perspex as a cement, and then irradiating the join with ultra-violet light, which causes the liquid material to polymerise into solid Perspex, with the result that the whole join made a continuous and homogeneous mass.

Some substances have the same percentage composition and yet, owing to differences in the relative position of the atoms within the molecule, they have different physical and chemical properties. Two such substances are ergosterol, which is in itself an inert fat, and calciferol or vitamin D_2, the anti-rickets vitamin. Some 25 years ago, it was discovered that irradiation had the ability to render certain foodstuffs capable of curing rickety conditions due to vitamin D deficiency, and there began an intense search by scientists to discover which components of the foodstuffs are effectively altered during the irradiation. It was soon demonstrated that the 'precursor' of the vitamin comes from the chemically inert portion of oils, and after much research it was found that ergosterol, after irradiation, possessed very powerful anti-rachitic properties. Today, ergosterol is dissolved in ether and irradiated with ultra-violet light, when a solution of the vitamin D is obtained.

One type of 'photo-chemical change' which is extremely important to many industries using dyestuffs, pigments, or colouring matters of any kind, is that brought about by the action of light on the colours. On exposure to light, many dyed fabrics, coloured or colour-printed papers, etc., change shade, or the colour may even disappear entirely. This 'fading' is of great industrial importance. Now one feature of radiation is that the shorter the wavelength of the radiation, the greater its energy content. Since energy has to be supplied to bring about the various chemical processes, including those involved in the fading of colours, ultra-violet light is much faster in its action than ordinary visible light. It is possible, by exposing the various dyed or coloured materials to the action of ultra-violet light, to obtain in a few days the results which are indicative of the fading effect that would normally occur over months or years. The quartz lamp can be used for these 'accelerated' tests, and also the carbon arc lamp. The value of accelerated tests is readily understood when we remember that the decision to market, or not to market, a particular product can depend on the results of these tests. By combining artificial rain, heating and freezing tests with the ultra-violet tests in cyclic order, it becomes possible to determine how materials will stand up to prolonged weathering; this kind of testing is used for paints to be used on buildings, motor-car bodies, and so on. Another example: in modern marketing, the first appeal is always to the eye, so that the packaging of the product becomes a most important matter, and if the carton fades and looks shoddy after a few days in the shop window, then the sales appeal of the product is greatly reduced, so that many manufacturers now give accelerated tests to samples of cards, papers, inks, and wrappers, to determine whether they will be durable.

Apart from the photo-chemical uses in industry, ultra-violet radiation has been utilised for the photo-physical changes it can induce. When short-wave rays act upon air, they can cause ionisation. Now, in many industrial operations, the weaving of rayon and the winding of celluloid, a charge of static electricity can be built up on the surface of the products. Such charged surfaces tend to repel each other, and thus make the material unmanageable in its passage through the machines. Static electricity may even become a danger in that sparks may be caused, capable of setting fire to certain materials, or exploding highly inflammable gases. It has been found that irradiation under suitable conditions with very short-wave ultra-violet rays neutralises the static electricity on the surfaces of these materials, thus reducing such dangers.

So far we have dealt with photo-chemical and photo-physical changes, and one other aspect remains to be considered, that is the photo-biological effects of ultra-violet light, which acts strongly on living cells. In general, the reactions of single cells show three phases: stimulation, irritation, destruction. For the higher organisms, such as animals and humans, doctors use the stimulant and counter-irritant phases, but for lower organisms or obnoxious living matter, such as bacteria, moulds and viruses, the destructive phase is the one to which our endeavours are directed.

Suitable ultra-violet irradiation destroys every kind of disease 'germ', but it should be emphasised that the rays cannot, of course, destroy 'germs' which are inside the human body, or inside food or filth, because they cannot penetrate the intervening layers of organic matter.

To spread infection, however, 'germs' have to travel. Many are carried by air currents or in water. 'Germs' that are in transit in air or in water are vulnerable to attack

by ultra-violet light, and can be killed by adequate exposure to ultra-violet light.

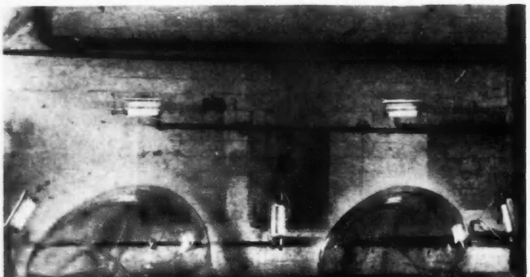
The sterilisation of drinking water to eliminate bacteria is usually done by chemical methods which are generally cheaper and less troublesome than using ultra-violet irradiation. There are some cases, however, where chemical methods of sterilisation are objectionable; these would spoil, for example, the waters used by brewers, by butter manufacturers, and by beverage bottlers. Such manufacturers find ultra-violet irradiation extremely valuable.

The sterilisation of air by means of short-wave ultra-violet light has been carried out in hospitals, child welfare clinics, crèches, and in a number of factories producing foods, beverages or drugs. Such treatment does not give completely sterile air, because, although the ultra-violet rays are killing germs every moment, fresh germs are being added by air currents carrying a portion of the germ population from protected surfaces, or by any animal organism existing in the space; but it does greatly reduce the germ population per unit volume of air.

In the U.S.A. a number of food shops exhibit their wares in cabinets which are fitted with ultra-violet lamps. The glass of the cabinet completely absorbs any of the short-wave radiation falling on it, so that the eyes of the customers cannot be damaged by the rays. Inside the cabinet, however, bacteria and mould spores floating in the air are rapidly killed by the rays and the air is kept sterile. Each time the case is opened to serve a customer, fresh airborne germs enter, but these, too, fall victims to the lamp's rays.

One of the most spectacular uses of ultra-violet light in industry utilises the fact that a number of substances will absorb the ultra-violet light falling on them and transform it into visible light so that the substance appears to glow. Directly the irradiating rays are cut off, the glow ceases; this phenomenon is termed 'fluorescence'.

For such work, the usual quartz arc discharge tube is used. This is enclosed in a light-tight box, having on one side a light filter which appears to be a perfectly black piece of glass. The filter has the property of absorbing all the visible light given out by the lamp, which would interfere with, or mask the fluorescence of, the materials examined, but it passes the ultra-violet light which causes the fluorescence. Substances placed before the filter fluoresce in a variety of colours and brilliancies, according to their origin, chemical constitution, method of manufacture, age or treatment to which they have been subjected.



Sections of 'Perspex' aeroplane astrodomes being welded by photo-polymerisation under u.v. light. (*Hanovia Ltd.' photo*).

In the food industry this lamp has found many applications. New-laid eggs appear to glow a brilliant crimson, which gradually fades as the egg ages until, with old eggs, the fluorescence is blue. Butter glows with a yellow fluorescence whereas margarine appears blue; the presence of refined lard or 'white grease' in lard alters the fluorescence colour; the keeping properties and palatability of powdered egg are shown by the fluorescence of certain extracts. Fluorescence tests enable the presence of minute traces of preservatives in foods to be detected. The same technique is also used to detect minute traces of glycerine in foodstuffs and other materials.

In agricultural work, various strains of barley can be distinguished by their different fluorescent colours; some appear green, others blue, and others again violet. By allowing rye grass seedlings to germinate on wet paper and examining this paper under the lamp, it is possible to distinguish between the perennial rye grass and the Italian rye grass type, since, where the rootlets have lain on the paper, a blue fluorescence is given by the Italian rye grass.

Bacteria or mould growth alter the colour shown by seeds under the ultra-violet lamp, and mouldy seeds admixed with good seeds can often be detected. The ergot fungus with its yellow-orange fluorescence can be detected in wheat and other food grain.

The leather industry uses the lamp to detect adulteration of natural tanning agents with synthetic tanning agents, a great many of both types having strong and characteristic fluorescent colours under different conditions. Minerals, gems, glass, water and sewage, textiles and rubber, paint, paper, and many other materials give a great deal of information as to their origin, method of production, and previous history when examined under the lamp.

Philatelists have found the lamp of interest in examining their collections since, for any given stamp issue, any addition of colour or other matter differing in composition from the original can be detected by the difference in the fluorescence between the original material and the added substance, and it is possible to detect reprints and forgeries by the difference between their fluorescence and that of the genuine stamp.

Collectors of other *objets d'art* also find the lamp valuable; for example, old marble fluoresces differently from freshly cut marble, or old marble that has been recut; many fossils which are embedded in stones are invisible in daylight, but glow under the lamp, standing out bluish or greenish against a violet background. A piece of bone or ivory which has been burnt differs in fluorescence from a sample which has turned brown with age, or through the use of chemicals in order to simulate old age. An old trick used to be to bury new ivory carvings in a manure heap or give them to a turkey to swallow; after these treatments, it appeared to be very old, but nowadays an examination under the lamp immediately reveals the way in which it has been treated, since the fluorescence of a fake is quite different from that of a genuine antique.

The police have made wide use of the lamp for the detection of forgeries, erasures and alterations to documents, and many large banks now use the lamp as a routine check for this purpose. The examination of letters to and from prisoners is now routine, as any writing in invisible ink is revealed by ultra-violet light.

SINCE the beginning of the sixteenth century the earth has been recognised as a huge bipolar magnet. In this article the Astronomer Royal deals with the location of the magnetic poles, which are not fixed, but 'wander'. This matter is of importance in connexion with the preparation of magnetic charts for the Admiralty, for which the Royal Greenwich Observatory is responsible.

Where are the Earth's Magnetic Poles?

SIR HAROLD SPENCER-JONES, F.R.S.

THE earth is a magnet and, like any other magnet, has two magnetic poles. If we move a compass in a small closed path encircling the pole, the needle will turn through 360°. At the pole itself there can be no preferential direction. The horizontal component of the magnetic field of the earth vanishes, and the lines of force are vertical, so that a dip-needle (a compass needle supported by a horizontal axis) must stand vertically. It is only at the two magnetic poles that the horizontal intensity is zero and the dip is 90°.

For navigational purposes it is desired to know the angle between the true north-south direction—the meridian—and the direction in which the compass needle points. Navigators refer to this angle as the *variation of the compass*, but its scientific name is the magnetic *declination*. It was so called because it is the angle by which the needle deviates, or declines from true north. In 1700 Edmond Halley constructed the first magnetic chart; he drew a series of curved lines on the map, each connecting the points at which the declination had the same value, so many degrees east or west of true north. This form of representation, by lines of equal declination or *isogonals*, is still used, enabling the navigator to infer the true north direction from his compass reading. The isogonals must all pass through the two geographical poles of the earth, because declination of the poles can have any value, according to the meridian to which it is referred. The isogonals must also pass through the two magnetic poles, since at these points, as well, the declination can take all values. For the construction of a chart of isogonals it is therefore necessary to know the positions of the magnetic poles.

The magnetic poles are at a considerable distance—of the order of 1000 miles—from the geographical poles and are not antipodal to one another. The line joining them passes the centre of the earth at a distance of about 700 miles. Being in cold regions, which are difficult of access, their positions have not often been determined and are not known with the accuracy that is desirable.

The first determination of the position of the north magnetic pole was made by John Ross in 1831 in the course of a voyage to discover a northwest passage. He reached a position at which the mean of several observations of the dip gave the value of 89°59′, just one minute short of the value of 90° to be found at the pole. This position was 70°5′N, 96°46′W, and was assumed to be sufficiently close to the true position. This first location of the north magnetic pole was a distinct contribution to knowledge but was not entirely satisfactory. The Canadian Arctic is a region of many magnetic anomalies, due to deposits of magnetic materials at or near the surface. We need to separate the localised effects from the general magnetic field of the earth to determine the true position of the pole, and this can only be done satisfactorily by a fairly detailed magnetic survey of the area. For the purpose of aerial navigation the earth's true field is alone of importance. The effect of a local deposit of magnetic material falls off inversely as the cube of the distance, and at heights greater than 10,000 ft. can be neglected.

For more than 70 years the Ross position of the pole was accepted and was used in the construction of isogonic charts. Early in the present century Amundsen established a temporary magnetic observatory on King William Island, south west of the Boothia Peninsula, where observations were made from November 1903 to May 1905; it served as a base station for a magnetic survey of part of the Boothia Peninsula. From a rediscussion of the observations then obtained the following positions of the magnetic pole were derived:

From observations of declination 70°35′N, 96°10′W.
From observations of horizontal intensity 70°40′N, 96°05′W.
From observations of dip 70°40′N, 95°55′W.

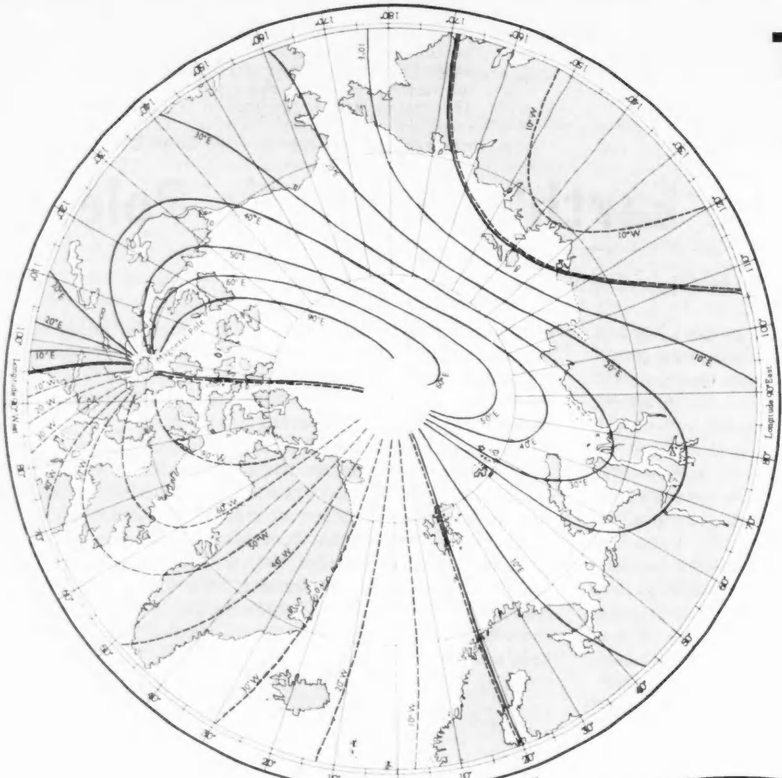
The three determinations are in satisfactory agreement and a mean position of 70°40′N, 96°05′W can be adopted, although the possibility of a fairly extensive magnetic anomaly cannot altogether be excluded. The Amundsen position agrees well with the Ross position and no further information has been obtained until recently.

The first attempt to assign a position to the south magnetic pole was made by Duperrey in 1825, who undertook a voyage of circumnavigation in the *Coquille* during the years 1822–25. The approximate position of the pole was given as 76°S, 137½°E. This was probably based on a rough estimate of the point to which the directions of the compass needle at several places converged. A similar method was probably used by D'Urville who in 1840, on his southern exploring expedition in the *Astrolabe* and *Zelée*, obtained the position 72°S, 136¾°E. A more reliable position was given by Sabine in 1844 from the magnetic observations of the Antarctic expedition of James Clark Ross* in the *Erebus* and *Terror* in 1841. This position was 75°S, 153¾°E. No further determination was made until the *Southern Cross* expedition under Borchgrevink in 1899, when from the observations made by Bernacchi a position of 72°42′S, 152°30′E was derived.

Three further determinations have been made during the present century. On Scott's *Discovery* expedition of 1901–04 numerous magnetic observations were made, both at a base station at McMurdo sound and on various sledge journeys. The magnetic observations were discussed by Chetwynd, and concordant positions of the magnetic pole

* James Clark Ross (who was subsequently knighted) was a nephew of Sir John Ross, who determined the position of the north magnetic pole in 1831.

THE MAGNETIC



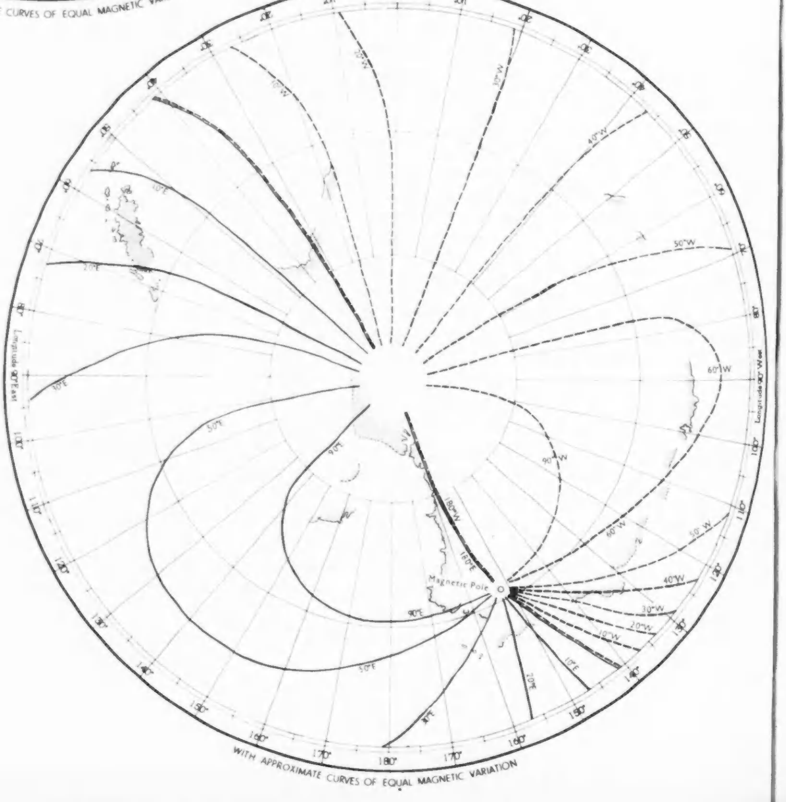
WITH APPROXIMATE CURVES OF EQUAL MAGNETIC VARIATION

(*Left*)—1. North Polar Chart of Magnetic Variation (for epoch 1942–5), based on limited observational data and the Ross-Amundsen position of the north magnetic pole.

Below

(*Left*)—3. South Polar Chart based on observations. Because of the very scanty data, the chart is largely hypothetical.

Westerly variation is shown by broken lines; Easterly variation is shown by continuous lines.



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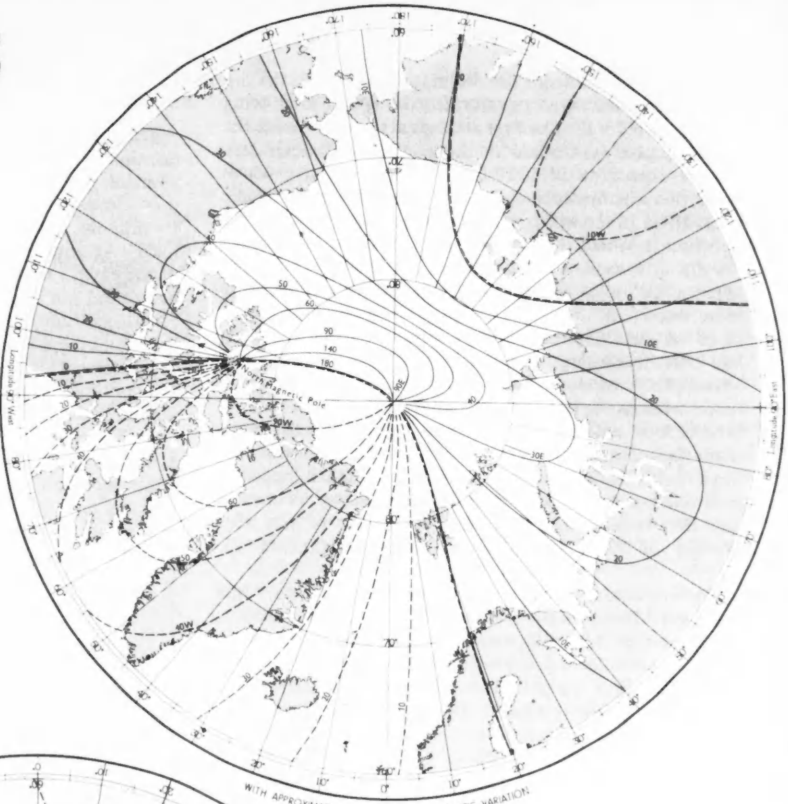
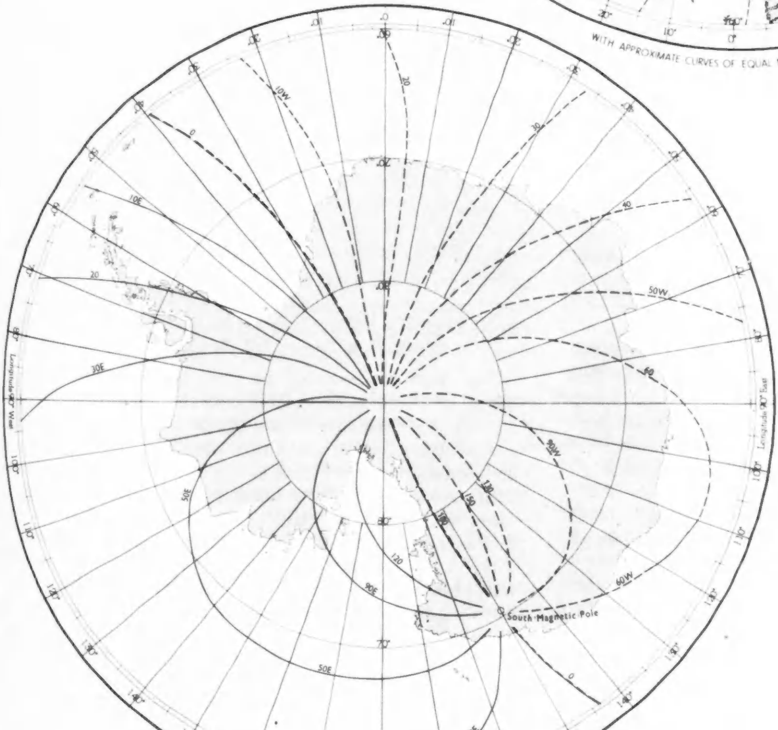
(*Right*)—2. North Polar Chart based upon the harmonic analysis of observational data between 60° N. Lat. and 50° S. Lat.

(*Right*)—4. South Polar Chart based upon the harmonic analysis of observational data.

All charts are for the epoch 1942–5. Based on charts prepared by the Admiralty and reproduced by permission of the Hydrographer to the Navy.





were deduced both from the declination and from the dip observations, the mean position for the epoch 1903 being 72°51′S, 156°25′E. The first attempt actually to reach the magnetic pole was made in the course of Shackleton's *Nimrod* expedition of 1907–09. The special party which made this attempt followed a projected line of magnetic force or, in other words, they travelled continually in the direction in which the compass needle pointed, observing the dip at intervals. The difficulty is that as the pole is approached indications of the needle become progressively more uncertain. A position was reached in which a dip of 89°48′ was obtained; from the rate at which the dip had been increasing, it was estimated that the pole was about thirteen miles further on. Proceeding for this distance, without the heavy baggage and the dip circle, because limited food made a hasty return essential, it was found that the compass needle still favoured a north-west direction; the observations proved that the south magnetic pole was north-west of the position assigned by Chetwynd and that it was also somewhat north-west of the final position of 72°25′S, 155°16′E reached on January 15, 1909.

The last actual location of the south magnetic pole was made on Mawson's Australasian Antarctic Expedition in the *Aurora*, 1911–14. A party set out to reach the magnetic pole, again following a projected line of magnetic force but approaching the pole from the opposite direction. At the furthest point reached a dip of 89°43′ was observed; it was estimated that the pole was at a distance of 71 miles in the position 71°10′S, 150°45′E. The south magnetic pole has still never been reached and there has been no detailed survey round it. A weighted mean of the 1909 and 1912 estimates would assign a position of approximately 71½°S, 152°E as the best estimate. It will be noted that the two magnetic poles are approximately equidistant from the equator but that their difference of longitude is only 112°, instead of 180°.

The North Pole Wanders

It has been mentioned that it is necessary to assign positions to the magnetic poles in order to construct isogonal charts. The forms of the isogonals are much more complex in the north polar area than in the south, and with scanty observational data it becomes difficult to interpolate. When engaged on the preparation of the Admiralty magnetic charts for 1922, I undertook a complete revision of the north polar area. It occurred to me that the problems would be simplified by constructing first the projected lines of magnetic force. These lines must all pass through the magnetic pole, but are not related in any way to the geographical pole; thus the system possesses only one singular point instead of two. This simplifies interpolation, and the projected lines of force can then be used for reading off the declination at as many points as are necessary. Discordances from recent observations, were greatly reduced by the revision, and in the account published in the *Geographical Journal* for 1922 I remarked:

> "It will be seen that the revision has considerably reduced the residuals which, however, are still systematic in their nature. It does not seem possible to reduce them further whilst adhering to the position which has been adopted for the magnetic pole. A better fit could have been obtained if a position about 2° further north had been adopted."

This was the first indication, I think, that the Amundsen position of the north magnetic pole was not in accordance with later observations, although it has continued to be used almost up to the present time. Yet there is no reason to suppose that the position of the pole should remain fixed. At any point on the earth's surface secular change of the earth's magnetic field is occurring: declination, dip, horizontal intensity, vertical intensity, and total intensity are all gradually changing. At the magnetic pole the dip is 90° and the horizontal intensity is zero; secular change in these elements necessarily implies that the same point does not continue to be the magnetic pole, unless by chance the secular change of dip was zero.

It is possible to obtain some information about the positions of the magnetic poles by a method due to Gauss, which does not depend on polar observations. Without making any hypothesis about the origin of the earth's magnetism, the magnetic potential can be expressed mathematically in an infinite series of spherical harmonics. It is not necessary to enter into any details of this mathematical representation; it is enough to say that harmonics after the fourth are small and that it is amply sufficient to terminate the series at the sixth harmonic. There are then forty-eight constants to be determined.

These constants having been determined, it is possible to calculate the latitudes and longitudes of the points at which the horizontal intensity is zero; i.e. the positions of the magnetic poles and, in addition, to construct isomagnetic charts for the polar areas, within which the observational data are scanty.

A harmonic analysis of the earth's field was made in this way by Sir Frank Dyson and Mr. H. Furner in 1923, based on the Admiralty magnetic charts for epoch 1922, prepared at the Royal Observatory, Greenwich. It was assumed in their discussion that the earth is a sphere, which is not strictly accurate. The following positions of the magnetic poles were deduced, with which are given for comparison the values adopted in the construction of the charts:

	Computed	*Chart*
N. Magnetic Pole	75°N, 100°W	71°N, 96°W
S. Magnetic Pole	71°S, 151°E	73°S, 156°E

The chart positions for the north and south poles were those of Amundsen (1904) and of Chetwynd (1903) respectively. We have mentioned above that the mean of the positions for the south pole obtained on Shackleton's and Mawson's expeditions is 71½°S, 152°E; this position is in close agreement with the computed position, and provides an additional verification of the validity of the method. The computed position for the north pole, however, is considerably to the north and somewhat to the west of Amundsen's position, in agreement with the indications I had found in the construction of the polar chart.

In this discussion the chart data for the whole of the earth's surface were used. In 1943 Mr. Melotte and I made a further harmonic analysis, based on the Admiralty magnetic charts for epoch 1942, but restricted to the region between latitudes 60°N and 50°S, as the data for higher latitudes were uncertain. Separate solutions were made, firstly on the assumption of a spherical earth and secondly

taking the spheroidal figure into account. The position of the magnetic poles derived on the two assumptions were as follows:

	Spherical Earth	*Spheroidal Earth*
N. Magnetic Pole	77° N, 103½° W	76° N, 102° W
S. Magnetic Pole	71° S, 150½° E	70° S, 150° E

Comparison of the spherical earth figures with the results of Dyson and Furner suggest that in the interval from 1922 to 1942 the north magnetic pole had moved in a direction somewhat to the west of north, but that there had been no appreciable change in the position of the south magnetic pole. The assumption of the spheroidal earth should give the more reliable positions of the two poles; it places both of them about a degree further from the geographical poles than the assumption of a spherical earth.

Aerial Observations

The discordance between the computed position of the north magnetic pole and the position adopted for the preparation of the charts seemed to be considerably larger than would be expected from the general uncertainty of the chart data and suggested that the position adopted for the north magnetic pole needed to be revised. Accordingly, when the plans for the north polar flights of the Lancastrian aircraft *Aries* from the Empire Air Navigation School, Shawbury, were under consideration, the question was raised whether useful observations could be made from the air. The problem of determining the position of the magnetic pole by observations in the air is not an easy one. It might appear at first sight that the rapid change in the declination in the vicinity of the magnetic pole would serve the purpose; but the directive power of the earth's field on the compass needle is then so small that its indications tend to become erratic. Measurement of the dip or of the horizontal intensity both depend upon a knowledge of the true vertical; any acceleration of the aircraft gives a spurious apparent vertical, and an error of 1° in the vertical would affect the value of the horizontal intensity by more than 0·01 gauss. Moreover, both dip and horizontal intensity vary slowly in the vicinity of the pole. During the war the magnetic airborne detector (M.A.D.) was developed for detecting submarines from the air; this equipment gives an accurate measure of the total intensity of the earth's field, but has not yet been adapted to measure the horizontal intensity.

For the polar flights of the *Aries* five types of non-stabilised compass were installed with needles differing widely in magnetic moment. Two types of gyro-stabilised compass were also installed. In addition, the aircraft was provided with a flux-valve dip meter for the measurement of the dip, a 3-axis flux-valve magnetometer, an astro-compass, and a directional gyroscope. Observations near the magnetic pole during the actual flights showed that the non-stabilised compasses gave reasonably good indications for horizontal intensities down to 0·02 gauss, while the gyro-stabilised compasses proved satisfactory down to a field strength of 0·03 gauss. As the strength of the field decreased, the average amplitude of oscillation of each compass increased considerably, particularly for the non-stabilised compasses. But by taking the means of many observations reasonably satisfactory results were obtained for values of the horizontal intensity as low as 0·01 gauss.

Two of the flights made by the *Aries* were of special interest for their bearing upon the position of the north magnetic pole. The first of these, made on May 19, 1945, started from Goose Bay (53° N, 60° W), proceeded north-westwards to the Boothia Peninsula, in the vicinity of the Amundsen position of the pole, then nearly northwards to Prince of Wales Island (73°40′N, 97°40′W). Retracing its track to the Boothia Peninsula, the aircraft then flew to Dorval near Montreal. It was found that the compasses performed satisfactorily over the Boothia Peninsula and gave more reliable indications than they should have done in the immediate vicinity of the magnetic pole. The observed declination remained fairly steady during the northern portion of the flight, showing that the magnetic pole had not been passed, for in passing across the pole the observed declination must change by 180°. The observations were compared with the values read off from special charts for the polar area prepared at Greenwich from the results of the harmonic analysis. According to these charts, the declination should have decreased by about 20° in the northern part of the flight; this decrease was not observed and the tentative inference can be drawn that the true position of the magnetic pole is not so far north as the computed position. The observations of horizontal intensity gave a value of about ·015 gauss at the Amundsen position of the pole and a minimum value of ·007 gauss at the most northerly point of the flight: they provide some confirmatory evidence that the pole is north of the Boothia Peninsula.

The second of the two flights referred to was the return flight on May 25–26, 1945 from Whitehorse (63° N, 135° W) to Shawbury, passing near to and slightly north of the computed position of the magnetic pole. On this flight the declination should have shown a change of 180°, whether the magnetic pole was in the Boothia Peninsula or in the computed position: but in the former case this change should have been progressive through some 1600 miles of the track, whilst in the latter within about 400 miles. The observed change was actually 180°, but occurred within a distance between these two extremes, though very much nearer the latter, being completed in about 600 miles. The evidence provided by this flight thus also supports the conclusion that the true position of the magnetic pole is between the Amundsen position and the computed position, but nearer the latter. The inference from the polar flights of the *Aries* is that the position of the north magnetic pole in 1945 was approximately 74° N, 100° W. The flights provided the first definite information that the pole had moved considerably northwards since Amundsen's observations in 1904.

Since these flights were made, independent confirmatory evidence has been provided by ground observations in the Canadian Eastern Arctic. In a report made in May 1947 to the Royal Astronomical Society of Canada by R. Glenn Madill of the Dominion Observatory, Ottawa, it was stated that the Dominion Observatory had been fully aware for many years that the magnetic pole was travelling in a northerly direction; this conclusion was based on the results of observations made periodically at repeat stations extending from Newfoundland to Alaska. Such observations to the south of the magnetic pole, in a region where the isogonals are practically linear, can reveal a change in the position of the point to which the isogonals converge. A similar result has recently been obtained in a

somewhat different manner by E. H. Vestine of the Department of Terrestrial Magnetism of the Carnegie Institution, Washington.

Epoch	*North mag. pole*		*South mag. pole*	
1904·5	70·5 N	96·5 W	..	..
12·5	70·9 N	96·8 W	71·2 S	150·5 E
22·5	71·4 N	97·2 W	70·2 S	149·2 E
32·5	71·9 N	97·6 W	69·0 S	148·1 E
42·5	72·6 N	97·9 W	68·3 S	146·2 E
45·0	72·8 N	98·0 W	68·2 S	145·4 E

During recent years the network of magnetic stations occupied by the Dominion Observatory has been extended considerably northwards of latitude 60°, over 200 additional stations having been added since 1943. There is now a fairly adequate coverage up to latitude 70° N. After the completion of Exercise Musk-Ox and the Eastern Arctic Patrol in 1946, when observations were extended to Denmark Bay, Victoria Island, and to Fort Ross, Somerset Island, it was possible to indicate a position of the north magnetic pole with some assurance. The position given by Madill was at 73¼° N, 94½° W, on Somerset Island, which agrees pretty well with the position obtained by Vestine for 1945 from his investigation of the secular change.

Some further observations were made by the Canadian scientists in the Eastern Arctic during the summer of 1947. A full scale airborne expedition was organised to take the scientists to their observation posts, a base camp being set up at Cambridge Bay. Magnetic observations were made at ten stations throughout the Northwest Territories, six of which were on the islands in the vicinity of the north magnetic pole. Two were on eastern Victoria Island; two on Prince of Wales Island; one on King William Island; one on the east coast of Boothia Peninsula. The full results of the discussion of these observations are not yet available, but Dr. C. S. Beals, Dominion Astronomer, has informed me by letter that the observations indicate a position for the north magnetic pole in the north-west part of Prince of Wales Island and that, as the distribution of the stations was favourable, this position supersedes the position on Somerset Island. The co-ordinates of the new position are not stated, but must be approximately 73¾° N, 100° W. This position is in very close agreement with that inferred from the *Aries* observations. The motion of the north magnetic pole therefore appears to be rather more rapid than Vestine's investigation suggested.

It seems pretty certain that the north magnetic pole cannot now be far from the position 74° N, 100° W. This position differs by about 2° from the position inferred for a spheroidal earth from the harmonic analysis.

The information about the present position of the south magnetic pole is somewhat contradictory. The mean of the locations assigned by Shackleton's expedition for 1909 and by Mawson's expedition for 1912 is in good agreement with the positions given by the harmonic analysis of the charts for 1922 and 1942. But Vestine's investigation indicates a more rapid motion for the south magnetic pole than for the north. The observational data for the south polar area is much more scanty, and I am inclined to place more trust at present in the position derived from the spherical harmonic analysis and to adopt provisionally 70° S, 150° E as the position of the south magnetic pole.

EINSTEIN'S NEW THEORY—*continued from p. 110*

and the dualism of physics-geometry, that is the dualism of electromagnetic versus gravitational field. He believed that a search for a simple geometry of our universe, but more general than that of Riemannian geometry, would lead us to a pure field equations that describe electromagnetic and gravitational phenomena. More than that: such a theory, if successful, should disclose to us the properties of elementary particles from which atoms are built and at the same time explain the motion of planets, stars, and nebulae.

Einstein believes that he may have solved this great problem. Indeed his new theory is fully a unitary theory. In it only the field appears and no sources of the field. The existence of matter will have to be deduced from the field equations by finding solutions that represent great concentrations of the field. The new theory is a purely geometrical theory. Whereas the electromagnetic field is characterised, in Maxwell's theory, by six functions, and whereas the gravitational field is characterised in Einstein's old theory by ten functions, the metrical field, according to Einstein's new theory, is characterised by sixteen (*i.e.* 10 + 6) functions. (To put this in technical language: the electromagnetic field is characterised by a antisymmetric tensor with six components, the gravitational field by a symmetric tensor with ten components, and the geometry of the new Einstein world by a general tensor of the second order with sixteen components.)

In General Relativity Theory, the Einstein field equations characterised the Riemannian geometry of our world. But the geometry of our world, according to Einstein's new theory, is a non-Riemannian geometry and in line with Einstein's new field equations. Every concept that appears in the new theory has its geometrical image. The distinction between purely physical concepts and those with a geometrical interpretation is gone. The distinction between matter and field is gone too. There is only the field that is both geometrical and physical; there are only the field equations that represent the geometry of our world and the laws of physics.

For weak fields, we regain from the new theory, the laws of the old theories, that is Maxwell's and the gravitational equations. This must be so, because every new theory must explain the phenomena that the abandoned theory explained. As always, so here, the discarded theory appears as a first approximation to the new one.

Although Einstein's new theory has many attractive features, we do not yet know whether it is a successful unitary theory. In the old theories, the existence of matter had to be assumed independently. Will the new theory succeed where the old theories failed? This is a crucial question and we don't yet know the answer. The situation is complicated. The modern development of physics concerns quantum laws which are valid inside the atom. It is not clear whether and in what way such laws could be deduced from Einstein's field theory. Yet one shouldn't be too sceptical. Einstein's work has always met temporarily with scepticism because his genius was ahead of his times. This happened twice and it may well happen again.

Far and Near

A.Sc.W. Conference on Food Problems

On one thing everybody was agreed at the A.Sc.W. Conference on the world's food and Britain's food-production needs. That was the fact that world population is increasing much faster than food supplies, while since a third to two-thirds of the world's population today are chronically undernourished. A number of famines are likely to occur in the next few decades unless some action is taken —but on the nature of what action must be taken there was a basic cleavage of opinion. "Grow fewer people," urged Huxley. "Grow more food," urged le Gros Clark, and these two speakers, with their respective theses, probably posed the most important issue of the Conference.

The Conference (held at St. Pancras Town Hall on March 4 and 5) opened with a showing of the documentary film *The World is Rich*.

This was followed by the reading of a message from Lord Boyd Orr, A.Sc.W. president, who was absent owing to illness. People who are short of food and the other primary necessities of life and believe that these can be obtained will overthrow any government or economic system which does not make them available. No military force can stop the spread of Communism among the underfed peoples of the world if the Communists can end hunger, he stated.

Lord Orr stated that arrangements were already being discussed in the U.S.A. for limiting areas under cultivation. A restrictionist plan would be doomed to failure, as it would result in farmers cutting their orders for industrial goods, and this would start a slump. The two problems, the scarcity of food and the unmarketed surpluses, should in a sane world cancel each other out. If the nations co-operated on concrete plans for increasing food production, ideological differences would in time lose their significance, he concluded.

Opening the proceedings with a paper on population problems, Dr. Julian Huxley, F.R.S., quoted some startling figures. In 1000 B.C. the world population was probably 100 million, in A.D. 1800 about 900 million, today about 2200 million. The present rate of increase is about 1% per annum. Even if population remained stationary, probably an increase of 15 to 25% in food production would be needed to bring up the level of the badly nourished. But in the last ten years population has increased faster than food production. Most countries, said Dr. Huxley, should be encouraged to decrease the reproduction rate. The basic problem, was to think of quality in place of huge, populations.

After Huxley came the nutritionist, Mr. F. le Gros Clark. He said it is a waste of time to reproach epidemiologists for keeping people alive before food is available because this disease control is a great human advance. Today medical science is a pacemaker to agricultural science, but its problems are rather different. Medical problems can be tackled by teams of a few hundred trained men; for instance, in three years a few hundred men cleared Cyprus of malaria (see Discovery, March 1949). But to raise food production in Cyprus or Greece requires the activity of four or five million peasants lacking money, equipment and seeds. They were typical of the peasant population of the world (amounting to 70% of the world's population). We need good scientific direction and a revolutionary change in farming methods, social conditions of the producers, and social relations—"a revolution as profound as the Industrial Revolution of 150 years ago," said the speaker.

This theme recurred in the paper by Dr. Bunting, Chief Scientific Adviser on the Tanganyika groundnut scheme. The transformation of peasant agriculture he saw as offering the greatest possibility for the future of world food supplies. Peasant farming has reached its limit of productivity unless there is now introduced co-operation; that is, social changes which will change the whole meaning of peasant farming. Dr. Bunting strongly favoured tropical development. The main problems —after the social ones—are breeding plants and stock resistant to drought and disease. The groundnuts scheme Dr. Bunting described as a prototype of future important developments, and said it was as difficult to judge the scheme in economic terms as to judge the spending of £12 millions on two Brabazon aircraft.

Sir George Stapledon, F.R.S., said Britain needed to achieve a balance between scrupulous care of the soil and production, between stock and crop husbandry.

Dr. G. A. Reay, Superintendent of the Torry Research Station, surveyed the possibilities in fish utilisation including its preservation and packing.

Unesco was represented by Mr. Maurice Goldsmith, who reminded the Conference that Unesco had made "Food and the People" its discussion theme for the year in order to produce an informed public opinion on the subject throughout the world.

A problem as old as agriculture itself—the prevention of food losses by insects, fungi and animal pests—was ably outlined by Mr. S. A. Barnett of the Infestation Branch of the Ministry of Agriculture. He said, that except for the difficulties of fighting field-mice, the means of control of most of these threats to man's food is well developed.

Natural History Museum. New Director

On May 1 Professor G. R. de Beer succeeds Mr. N. B. Kinnear as director of the Natural History Museum at South Kensington.

Professor de Beer, who is 50, is Professor of Embryology at University College, London. After graduating with first-class honours in zoology at Oxford in 1921, he became a Fellow of Merton College (1923–38), and was sub-warden of that college from 1935 to 1937. He was senior demonstrator in the zoology department of Oxford University from 1926 to 1938, when he left Oxford for University College, London. He has written numerous books, including the very well-known *Vertebrate Zoology*. He is science editor of the Home University Library and general editor of the Clarendon Press's monographs on animal biology.

He was elected a Fellow of the Royal Society in 1940, and is the ex-president of the Linnean Society.

The Fuchs Case

Dr. Klaus Emil Julius Fuchs was sentenced to 14 years' imprisonment at the Old Bailey on March 1 for betraying official secrets about atomic research to Russian agents. He has been described as the most successful spy in history, and certainly the information he gave away eclipsed in importance the facts that are sold by ordinary spies. He pleaded guilty to passing on secrets on four different occasions—in 1943, 1944, 1945 and 1947. On the first occasion he was in a position to disclose details about the critical size for an atomic bomb which he had calculated as a member of Prof. R. E. Peierls's team. From 1944 to 1946 he worked at the Los Alamos atom station, where the construction of atomic bombs was perfected. In 1947 he was head of the theoretical physics department at Harwell, into which data from all other departments would pass.

Weather Exhibition at Science Museum

In honour of the Royal Meteorological Society's centenary, the Science Museum has a special exhibition portraying modern ideas on weather and meteorology, and their influence on everyday life. It will be open until June 25.

Synthetic "Mica"

American research workers of the National Bureau of Standards have been able to produce a new crystalline substance which, it is claimed, is actually able to withstand considerably higher temperatures than natural mica. It was believed that mica itself could have been synthesised, but this would have meant duplicating its natural conditions of formation, involving extremely high temperatures and pressures. Even if achieved on a small scale, such a process would have been difficult to translate into quantity production. The new synthetic mineral has the formula, $K_4Mg_{12}Al_3Si_{12}O_{40}F_8$, and is equivalent to one natural form of mica except that fluorine atoms take the place of hydroxyl groups.

The raw materials used are quartz, magnesite, bauxite and potassium fluorosilicate. The first three substances are first roasted, and then ground and mixed with the fluorosilicate. The mixture is melted in a crucible lined with platinum foil at a temperature of 1400°C. On cooling, the 'synthetic' mica crystals grow from a tiny seed at the bottom of the crucible.

Night Sky in April

The Moon.—Full moon occurs on April 2d 20h 49m U.T. and new moon on April 17d. 08h. 25m. The following conjunctions with the moon take place:

April			
2d 00h	Mars in conjunction with the moon	Mars	3° N.
12d 13h	Jupiter ,,	Jupiter	3° N.
13d 01h	Venus ,,	Venus	4° N.
19d 04h	Mercury ,,	Mercury	1° S.
28d 07h	Saturn ,,	Saturn	0·02 N.
28d 23h	Mars ,,	Mars	0·8° N.

In addition to these conjunctions with the moon, Venus is in conjunction with Jupiter on April 5d 11h, Venus 2·3° N.

The Planets.—Mercury is an evening star, setting at 18h 50m, 20h 38m, and 21h 07m., at the beginning, middle and end of the month respectively, and attains its greatest eastern elongation on April 23. Venus is a morning star, rising about 1½ hours before the sun on April 1 and a little over an hour before the sun on April 30, attaining its greatest western elongation on April 11. It shines as a star of mag. −4 for most of the month, and on April 12 half the illuminated disk is visible with a pair of binoculars. Jupiter is a morning star, but is not easily seen till after the middle of the month, when it rises nearly 1½ hours before the sun; on April 30 it rises 1h 50m before sunrise, but is too low in the heavens to become a conspicuous object. Saturn is visible throughout the night in the constellation of Leo. On April 2 there is a total eclipse of the moon, visible in the British Isles. The following are the circumstances of the eclipse in which many readers will be interested:

Moon enters penumbra	April	2d	18h	09·3m
Moon enters umbra	,,	2d	19h	09·0m
Total eclipse begins	,,	2d	20h	29·5m
Middle of eclipse	,,	2d	20h	44·1m
Total eclipse ends	,,	2d	20h	58·7m
Moon leaves umbra	,,	2d	22h	19·2m
Moon leaves penumbra	,,	2d	23h	18·8m

These figures refer to Greenwich, but are approximately correct for other places in England. One important fact should be noticed. On April 2 at Greenwich the moon rises at 18h 22m (6.22 p.m.) or about 13 minutes after it enters the penumbra, so observers there cannot see the beginning of this phenomenon. The moon is always full when a lunar eclipse occurs, and this is the first full moon which takes place after March 21. Bear in mind the rule for finding Easter. It is the first Sunday after the full moon, which happens upon, or next after the twenty-first day of March; and if a full moon happens on a Sunday, Easter Day is the Sunday after. This year full moon is on a Sunday, and hence Easter Day is not on Sunday April 2, but on the following Sunday April 9.

Killing Weeds on Lawns

RECOMMENDATIONS for the rates of applying selective weedkillers to turf are given in the 1949 volume of the *Journal of the Board of Greenkeeping Research.* The Board's Research Station has carried out experimental trials to determine the amounts of 2-methyl-4-chloro-phenoxy-acetic acid (*MCPA*) and 2:4 dichlor-phenoxy-acetic acid (2:4*D*) which in a single spray application will give the best weed control. The results were as follows:

For *MCPA*, using the sodium salt known as 'Methoxone' control was obtained with: 2 lb. (per acre) for sensitive weeds such as plantains, under favourable conditions, 4 lb. for general weeds under good conditions, 6 lb. for resistant weeds.

Using the sodium salt of 2:4*D* the recommended rates are given as: 2 lb. per acre for sensitive weeds under good conditions and 4 lb. per acre for general weeds under less favourable conditions.

When these weedkillers are used as dusts instead of sprays slightly greater quantities may have to be used.

These recommended applications have been found successful with most weeds in turf, but clover and yarrow have proved difficult to control. Sometimes repeated applications of weedkiller have failed to kill these two weeds; on other occasions a single spray has been effective. A warning is given that heavy applications, if repeated, may also kill the grass.

On newly seeded turf selective weedkillers cannot with safety be applied for at least three months after seeding and with turf newly established from sods a trial on a small area first is a wise precaution.

FOAMED LATEX

TWENTY-FIVE years ago three rubber technologists, Mr. E. A. Murphy, Mr. Chapman (of the Dunlop Rubber Company), and Mr. F. C. Jennings decided to investigate the properties of rubber latex, which was then still something of a mystery to scientists, though the rubber latex from the rubber-tree had long been the ultimate raw material of the natural rubber industry. Their line of attack, which was part of the firm's long-range policy of scientifically studying the commercial possibilities of latex, was the possible development of a light sponge rubber.

Dr. Schidrowitz invented a sponge rubber in 1914; this was prepared by grinding and rolling rubber and somewhat resembled the rubber out of which Sorbo balls are made, but it was not a commercial success. Mr. Chapman and Mr. Murphy thought it might prove possible to obtain a stable foam by whipping up the latex as one whips up cream, and adding suitable agents to make the foam set to form a sponge-like material. This simple idea was to take seven years to become a commercial possibility.

First industrial experiences of the handling of liquid latex was gained in the manufacture of rubber goods such as hot-water bottles, made by dipping moulds into concentrated latex or by electro-deposition on to moulds, and in the manufacture of rubber thread by extrusion. But this was all on a small scale. A great drawback was the erratic state in which latex arrived in this country from the Far East; it came over in kerosene tins and in a variable state of preservation and concentration. When the scientists did research on this material they found that their results could not often be repeated. Thus commercial methods of concentrating, shipping and storing liquid latex had to be worked out before its development could properly proceed.

Latex is a liquid dispersion of rubber in water, containing about 35% rubber; it is white in colour. The liquid latex is somewhat similar to milk in behaviour, in that bacterial action can take place when latex is kept, to result in the 'curdling' of the solution; this leads to the production of a mass of sticky, spongy rubber. The addition of one-half per cent of ammonia is sufficient to neutralise acid produced by the bacteria and act as a preservative. At the Malayan rubber depots liquid latex is concentrated by centrifugal action, stored in large tanks, shipped in tankers to Britain and transferred to shore installations from which 5000-gallon road tankers convey it to the rubber works. Despite the millions of gallons annually used in production, the quality of latex is maintained at the definite standard.

The 'curdling' property of latex, inconvenient though it be naturally, appeared to the Dunlop scientists to hold the key to a sponge rubber capable of being moulded. It proved a simple matter to coagulate the rubber by the addition of a little acetic acid. The acidified latex was then frothed up by the addition of a little soap solution and the whole beaten up with an egg-whisk. The next problem was to find a stabiliser so that the bubbles of the whipped-up, coagulated latex did not burst. This stabiliser or gelling agent prevented the air and liquid mixture from separating out, so that a pourable foam resulted. This stabiliser was not discovered until 1929. It is sodium silico-fluoride, with bentonite (a white clay consisting mainly of colloidal silica) added as a preservative. The foam could now be poured into moulds and cured. The amount of sodium silico-fluoride present determines the period for which the foam remains pourable; it also affects the ratio of rubber to air in the foam.

After the discovery of the gelling agent pilot manufacture was started using a small, electrically operated cake-mixer. The mixers used today in the commercial preparation of foamed latex are, except for minor alterations, giant-sized cake-mixers.

As usually happens, parallel work on sponge rubber was being prosecuted entirely independently on both sides of the Atlantic. The American investigator was Mr. F. H. Untiedt, a U.S. patent attorney, who used no gelling agents and dried his dense foam at room temperature, producing thin sheets. He was

unable to commercialise his process, though he offered it to the four great American rubber companies.

On March 21, 1929, two British patents, Nos. 332,525 and 332,526, were issued. The former covered the combined whipping and gelling process and represents the birth of latex foam industry; the latter covered the simple whipping process. On October 7, 1930, Untiedt's process was granted the United States Patent No. 1,777,945. In 1932, having failed to interest American concerns, he sold the patent to The Dunlop Rubber Company, although, "the commercial possibilities of latex foam rubber could not be foreseen". On April 5, 1932, the British gelling and whipping process was granted a U.S. Patent (No. 1,852,447). Thus Britain held the master patents of a new industry.

But much additional development work remained to be done, and indeed, at one time it seemed doubtful whether commercial production would ever eventuate owing to the high cost of development. Latex foam rubber came into industrial production, though on a small scale, about 1932. During the war its manufacture ceased, but was restarted on an enlarged scale in 1946. Instead of a conveyor-belt production system, unit production was installed, with the workers working in small groups, arranging their jobs among themselves.

Today the latex from the storage tanks is blown into reacting chambers, where the ammonia is reduced to less than $\frac{1}{4}$%. It is filtered and catalysts, vulcanisers, carbon black and zinc oxide suspended in soap and glue are added. The mixture is matured at a controlled temperature in the maturing tanks. From the tanks it is drawn off in a measured amount by the self-contained process units for their whipping machines. A given quantity of setting agent and soap is added, according to the predetermined ratio of air and rubber. The whipping process now begins, and when it is complete the foam produced is poured into moulds before it collapses or the gelling agent reduces its mobility. The moulded articles are then cured by steam heating in a matter of some thirty minutes.

The articles, which may vary from seat arms to double-bed mattresses, are packed into centrifuges, which, revolving at 7000 revolutions per minute, remove most of the water. Inches-thick mattresses reduce to less than an inch thick under the centrifugal force; but the natural resilience enables them to regain their shape and size immediately the centrifuge stops. They are then dried at 150° F.

The application of foamed latex to motor-car and bus seating has allowed much more comfortable design than possible with the old spring and frame seating. In fact a technical department has had to be created to tie-up with the requirements of the motor industry, cinemas and export requirements. The first big consignment of foamed latex seats went to the Shakespeare Memorial Theatre, Stratford-on-Avon.

I. B. N. EVANS

The Bookshelf

How Chemistry Works. By Arthur J. Birch. (London, Sigma Books, 1949; 215 pp. 8*s.* 6*d.*)

A Direct Entry to Organic Chemistry. By John Read. (London, Methuen, 1948; 268 pp. 4*s.* 6*d.*)

THE author of the first book has chosen no easy task. To quote from his preface, he "attempts to discuss seriously the *how* and *why* of chemistry without the obscuring mass of detail necessary in a text-book . . . *How Chemistry Works* is intended chiefly for the layman . . ." Unfortunately, he has not altogether succeeded in his aim; his book, admirable in many ways, falls a little wide of its target. It should in fact prove a useful summary of the whole field for chemistry *students* of inter-B.Sc. level, particularly as a revision book; but as for the poor layman, however interested he may be in science, some of the book will go right over his head. The interpretation of science to the non-scientist calls for a peculiar brand of skill, one unfortunately not possessed by all scientists; Dr. Birch has it to some extent, but like many specialists he tends to overrate the layman's capacity for sustained interest in an unfamiliar subject. He is, however, deeply conscious of the dignity and beauty of chemistry: the history of a carbon atom is a tale of the beauty and terror, the wonder and pity of a thousand million years. "The layman . . . can gain a heightened perception of, and pleasure in, the workings of the world by applying even a slight knowledge of fundamental principles." Passages such as these will justify the book to the layman more than all the formulae in it.

Parts of the historical introduction may confuse the layman, particularly the treatment of the phlogiston theory which would have been better omitted altogether. The chapters on "The Invisible World" and "Aims and Methods" are excellent reading, but the later ones on "Breakdown and Synthesis" and "Life and Death" demand a concentration which few readers other than students will be able or willing to give.

The book is spoiled, too, by the shoddiness of its illustrations, layout of formulae and lettering of captions, points which deserve the greatest care in any book. Fig. 1, symbolising alchemy and modern chemistry, is in particularly deplorable taste.

It is interesting to compare this book with Prof. John Read's *A Direct Entry to Organic Chemistry*. Here the author has chosen a more restricted field; he has, too, a maturer style which perhaps makes for rather less heavy going. But for the student, the two books together will cover a very wide and useful field of reading.

DENIS SEGALLER

The Coming Age of Wood. By Egon Glesinger. (London, Secker & Warburg, 1950, pp. 279, 12*s.* 6*d.*).

IN an age in which plastics and light metals have superseded wood in some directions, while on the other hand vast consumption in rayon and paper has called forth urgent demands for reafforestation to balance denudation, any book on a 'Coming Age' for wood should prove stimulating.

Wood is in universal demand, is abundant and is inexhaustible provided scientific management and replacement of forests are assured. Those are Dr. Glesinger's maxims, his themes set out in a vivid American style and illustrated with original coloured diagrams. The style, with vigorous captions, will appeal to the layman and prove easy reading; to the more technical-minded it will prove also entertaining.

Chambers's Six-Figure Mathematical Tables. By L. J. Comrie. Vol. 1, Logarithmic Values. Vol. 2, Natural Values. (Edinburgh and London, W. & R. Chambers, 1948–9; each volume has 576 pages, 42*s.* per volume).

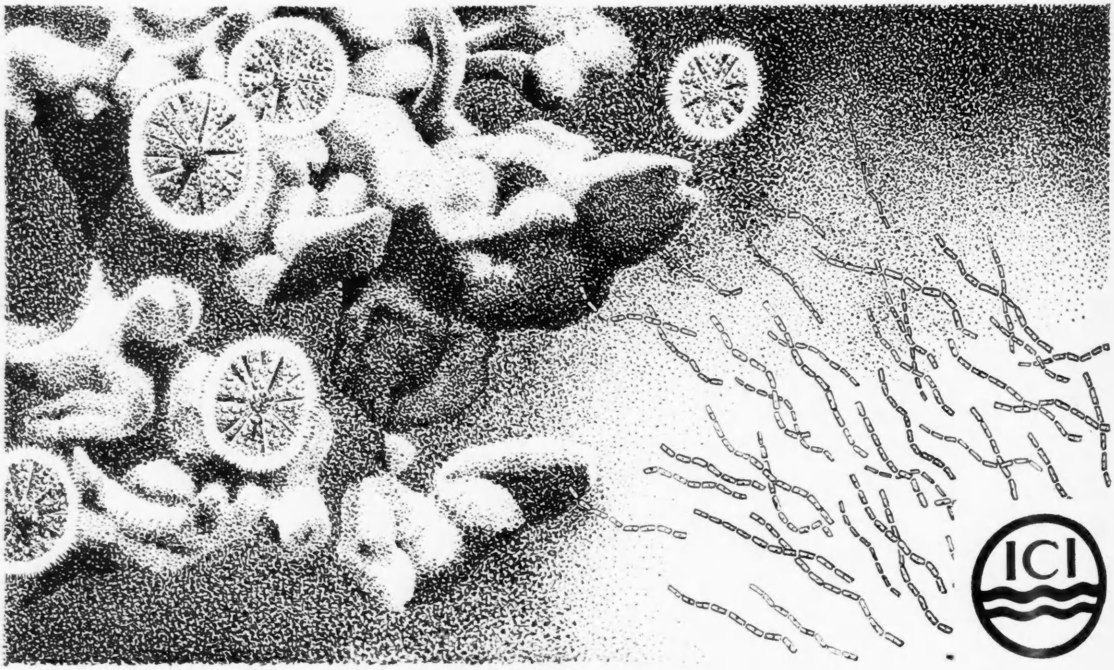
SINCE 1844 Chambers's *Mathematical Tables* has been a (perhaps one should say *the*) basic element in the computer's equipment. In our own time Dr. Comrie has become well known as a (and again perhaps *the*) most skilful computer and provider of computing aids. The combination of the two has produced something of first class value. The link between the earlier Chambers's tables and the new is, as a matter of fact, little more than that of a publishing tradition, but in a sphere where lay-out and accuracy count for so much that is an important link.

The tables are now given to 6 figures instead of the old 7, for sound reasons connected with changes in computing practice. They are presented in two volumes. The first, intended chiefly for those who must work without benefit of calculating machine, contains logarithms, anti-logarithms, logarithms of the trigonometrical functions (with arguments in the several forms that may be needed), of hyperbolic functions and of the gamma function. The second, for those who use calculating machines, contains natural values of the trigonometrical, exponential and hyperbolic functions, the gudermannian, and the inverses of all these, powers, roots, reciprocals, factors and factorials, the gamma function, the probability integral (in several forms), besides formulae and coefficients for interpolation, differentiation and integration. Both volumes contain the various minor auxiliary tables that one might expect. The nautical, astronomical and surveying tables, which were just so much waste paper to the average user of the old Chambers's tables, have now disappeared.

The typography and lay-out are remarkably clear and Dr. Comrie's experience has been used to serve the user down to to the most minute details. If one minor suggestion may be offered for possible incorporation in future editions, it is that the table of proportional parts in Volume I should be repeated in Volume 2, so that the happy owner of both volumes might, by using them simultaneously, avoid the trouble of working on two separate openings for one computing process.

S. LILLEY.

Printed and Published in Great Britain by Jarrold & Sons, Ltd., Norwich. Editorial Offices: 244 High Holborn, W.C.1.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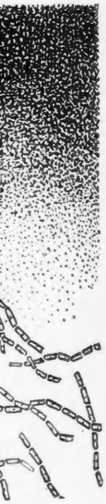

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